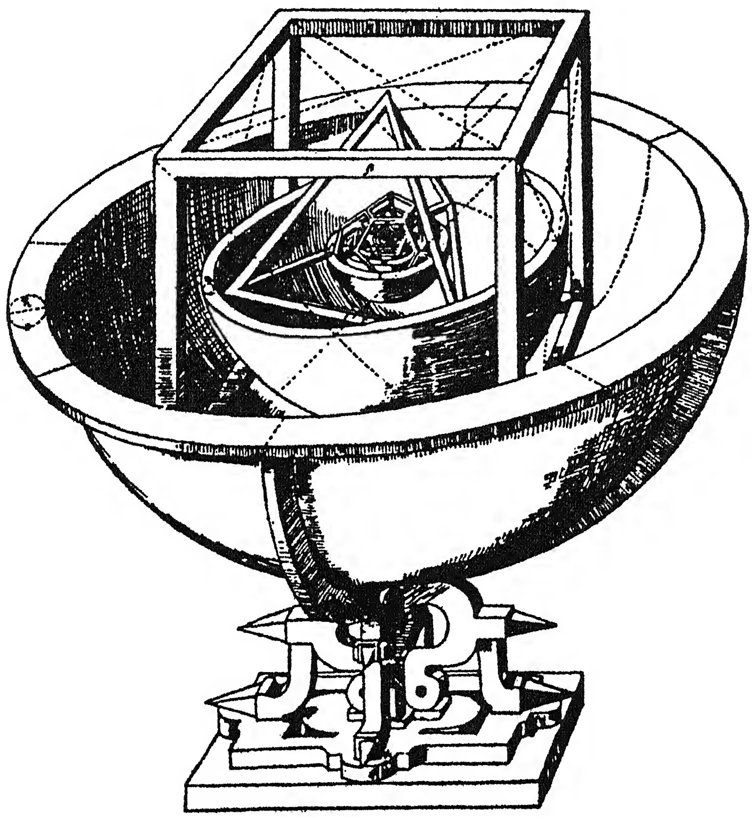
Resonance

September 1996 Volume 1 Number 9

journal of science education



Planets Move in Circles ❖ Secretary Probler

Distribution of Diversity ❖ Will a Computer B

the World Chess Champion? ❖ Plastic Diam

Resonance **is a monthly journal of science education published by Indian Academy of Sciences, Bangalore, India.**

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Editorial

N Mukunda, Chief Editor

When Isaac Newton acknowledged his debt to his predecessors by saying he had been able to see farther because he stood on the shoulders of giants, he had in mind principally Galileo Galilei and Johannes Kepler. From the former he inherited the foundations of mechanics distilled from careful terrestrial experiments, and upon which he built his own magnificent "system of the world" based on his law of universal gravitation. From the latter he inherited the three fundamental laws of planetary motion, known after Kepler's name. These laws concern respectively the elliptical shape of each planetary orbit; the constancy of the areal velocity; and the connection between time period and orbit size when different planets are compared with one another. Kepler discovered his laws by painstaking analysis of the astronomical data compiled by Tycho Brahe before him; this lasted many years, and the sequence of their discoveries is in fact not the same as their numbering. Incidentally in the case of the third law, there was a gap of several years between discovery and announcement — something unimaginable in today's intensely competitive scientific world!

Sometime before all this, however, Kepler had convinced himself that there was a "divine connection" between the sizes of the planetary orbits and the five regular polyhedra known since Greek times. This was his picture of the heavens of his time, "a harmony of the spheres", and is what is reproduced on the front cover. The orbits of successive planets were enclosed in a sequence of these solid figures in nested fashion; this "truth" had come to him in a flash while teaching mathematics class at school. Amazingly this construction gave a pretty good fit to the data then available to him!

About Sonya Kovalevskaya

"An early indication of her talents was her ability to make sense of the sine function all by herself."

"Her thesis contained results on degenerate Abelian integrals which reduced to elliptic integrals, and on the shape of Saturn's rings."

Our excuse for presenting Kepler's construction is an article by Thanu Padmanabhan describing a velocity space treatment of the Kepler problem — the motion of a body in a central inverse square law of force. While this is to be found in some text books, it is not too widely known and appreciated. Padmanabhan's article should be of interest to students and teachers alike for its pedagogical level and attractive style. The many miracles of the inverse square force law — including the reason for and existence of an unexpected constant of motion — are beautifully explained.

This problem reappears in quantum mechanics as the "Coulomb problem" — with the inverse square law of force being electrostatic in origin. It will interest readers to realize that the same miracles played an important historic role again in the development of the new mechanics. After Heisenberg's discovery of matrix mechanics in summer 1925, and before the advent in early 1962 of Schrodinger's wave mechanics based on the more familiar mathematics of partial differential equations, Pauli solved the Coulomb problem algebraically exploiting its unusual constant of motion. This was a triumph for the new ideas ushered in by Heisenberg.

Turning to the back cover, for the first time we feature a woman — something we hope to do regularly — the remarkably talented mathematician Sonya Kovalevskaya. In a brief article-in-a-box, Mythily Ramaswamy describes her life and carreer in mathematics, the turbulent times she lived in and the prejudices she had to contend with both on the social and the professional fronts. That she was able nevertheless to produce work of the highest calibre in mathematics, and also turn to literary pursuits, speaks both for her talents and strength of character.

One may say "The eternal mystery of the world is its comprehensibility. " It is one of the great realizations of Immanuel Kant that the postulation of a real external world would be senseless without this comprehensibility.

— Albert Einstein

Sonya Krukovskaya

The first woman mathematician of modern times

Sofya* Vasilievna Krukovskaya was born on 15th January, 1850 in Moscow in an aristocratic family. By nature, she was an intense and serious person. An early indication of her talents was her ability to make sense of the sine function all by herself. It was then, her conservative father agreed to allow her to take some calculus lessons from Prof Strannoliubsky in St. Petersburg.

Russian society being very conservative at that time, women had no hopes of higher education or a career. Many young women tried to go to the west but could travel only with the permission of their husbands or fathers. In some extreme cases, a young woman entered into a "marriage" for namesake with a liberal "husband" and the couple chaperoned a group of her friends to the west. Vladimir Kovalevsky, a liberal and publisher of many scientific texts "married" Sofya in 1868 and the couple escorted her sister Anyuta, to the west in early 1869.

Sofya and Vladimir settled down in Heidelberg where she studied for a year with du Bois-Reymond and Konigsberger, both students of Karl Weierstrass, one of the giants of mathematics. This too was possible only after her strenuous efforts at getting the administration to agree that she could attend courses with the permission of the professors. In the fall of 1870, she left for Berlin to seek out her teacher's teacher, Weierstrass. As he was forbidden by university rules to allow her to attend his lectures, he started giving her private lessons. Thus Sofya was able to catch up on her mathematical education, in spite of turbulent events in her personal life. In a period of 18 months, she wrote 3 dissertations under Weierstrass's direction. He appealed to the somewhat more liberal University of Göttingen for her doctoral degree which she received in 1874 to become the first woman Ph.D.

After their return to Russia in 1875, Sofya and Vladimir (who had a Ph.D. in geology) were unable to find any suitable position and hence turned to real estate business investments which eventually failed. Meanwhile in 1878, her daughter, Fufa was born.

In March 1881, Tsar Alexander II was assassinated and the couple, with their radical ties, found it safer to move to the west. Sofya settled down in Berlin to work on Lame's equations. Vladimir returned to Russia and was getting deeper into financial trouble and finally committed suicide in April 1883. This was a rude shock to Sofya. In spite of that, she managed to finish her work. Meanwhile Mittag-Leffler had arranged a post for her in Stockholm University. She felt that it was her moral

obligation to clear Vladimir of the charges against him. So she returned to Russia and managed to establish his innocence. Then leaving Fufa with her friend Julia she sailed to Stockholm in November 1883, to become the first woman professor of mathematics. The following years were quite productive mathematically. Her work on Euler's equations fetched her the Bordin Prize from the Paris Academy in 1888. But in February 1891, her life came to a sudden end after a brief illness.

In her thesis, she had proved an important theorem on the existence and uniqueness of an analytic solution for partial differential equations with analytic coefficients (now known as the Cauchy-Kovalevskaya theorem). Her thesis also contained results on degenerate Abelian integrals which reduce to elliptic integrals, and on the shape of Saturn's rings. The important work which fetched her the Bordin prize was on Euler's equations describing the motion of a heavy rigid body, with one point fixed like a top or a pendulum. Her other work includes the one on Lame's equations for light refraction in crystals.

In the field of literature in the last five years of her life she produced a memoir of her childhood and adolescence, a novel *A Nihilist Girl*, two plays, a small body of verse, a collection of short stories and some essays.

Thus in spite of the uncertain political atmosphere and a turbulent personal life, Sofya Kovalevskaya managed to pursue a successful mathematical career thanks to her talents and determination. Of course, the influence of Weierstrass and the extraordinary efforts of Mittag-Leffler are equally important factors that helped her. She is recognized as the first woman mathematician of modern times, who through her achievements, opened many doors for other women in the field of mathematics.

*Sometime in her adult life, Sofya acquired the name Sonya by which she is better known.

Suggested Reading

- E T Bell. *Men of Mathematics*. Simon and Schuster, 1937.
- B Stillman. *A Russian Childhood*. Springer Verlag, 1978 (translated, edited and introduced by Stillman from Sofya's original, *Memories of childhood in Russia*).
- A H Koblitz. *A convergence of lives, Sofya Kovalevskaya: scientist, writer, revolutionary*. Birkhäuser, 1983.
- Roger Cooke. *The mathematics of Sonya Kovalevskaya*. Springer Verlag, 1984.

Mythily Ramaswamy

TIFR Centre, IISc Campus, Bangalore

Science Smiles

R K Laxman

I've a Master's Degree in Library Science. But it's a mystery why the books in that section are never returned!

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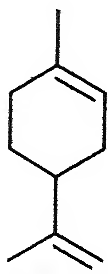

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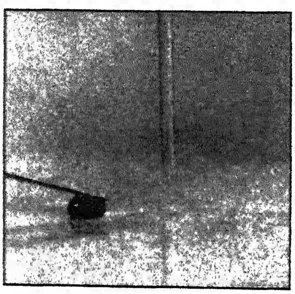

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GENERAL ARTICLES

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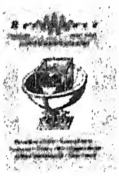


Front Cover

The cover illustration is from Johannes Kepler's book. He believed that the relative distances of planets from the sun could be understood based on a modél involving the five regular solids. Unlike his laws of planetary motion, this idea of Kelpler's has not survived to the present day.

Back Cover

Sonya K (Sofya Vasilievna Krukovskaya)
(illustration by Prema Iyer)

Life : Complexity and Diversity

5. Distribution of Diversity

Madhav Gadgil

Madhav Gadgil is with the Centre for Ecological Sciences, Indian Institute of Science and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. His fascination for the diversity of life has prompted him to study a whole range of life forms from paper wasps to anchovies, mynas to elephants, goldenrods to bamboos.

Diversity of life is unevenly distributed over the surface of the earth; especially rich are the tropics, mountainous regions and island archipelagos. Lying at the trijunction of Africa, temperate Eurasia and tropical Southeast Asia and enjoying a great diversity of environmental regimes, India ranks about the 10th amongst nations in terms of its diversity of species.

Hotspots of Diversity

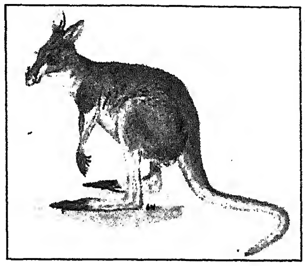
All parts of the globe are obviously not equally rich in the diversity of life. On land, the tropics are far more diverse, on the sea bottom, the cold, unchanging depths of oceans are especially rich. Malaysia and Norway have almost identical geographical areas of around 32 million ha, roughly 10% of India's. But while Malaysia has 12000 species of higher plants, Norway has only 1600. Malaysia has 158 species of frogs, salamanders and their relatives; and 268 species of reptiles. Norway has only 5 species of each group. Malaysia has 501 species of birds and 264 species of mammals while Norway has 264 species of birds and only 54 of mammals. The much greater variety of tropical life has been attributed to a variety of reasons; greater productivity, year round occurrence of conditions favourable to life and lower levels of the impact of ice ages in the geological past. All these factors have led to higher levels of species packing in the tropical latitudes.

Species turnover levels are particularly high where the environmental regimes change rapidly.

Species turnover, replacement of one set of species by another, is the second component of species diversity. Species turnover levels are particularly high where the environmental regimes change rapidly as at the seashore. In terms of broader land regions, mountain tracts are apt to have high levels of species

turnover. This explains why mountainous tracts like our own Western Ghats and Eastern Himalaya as well as the Eastern Arc Mountain of Tanzania figure among the world's *hot spots* of biological diversity (*Figure 1*).

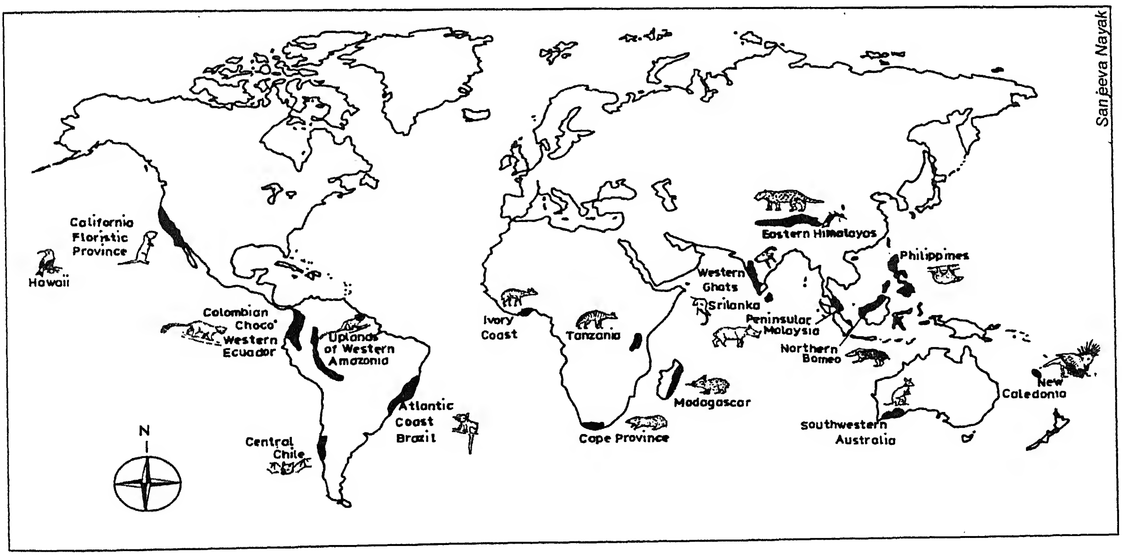
An excellent measure of geographical turnover, the third component of species diversity is the proportion of species unique to a region. Species restricted to a given region are said to be *endemic* to that region. Islands by virtue of their long isolation are especially rich in endemic species. Australia leads all countries of the world in the number of endemic species of mammals (210) and reptiles (605) (*Figure 2*). It is next only to Indonesia, another island nation in the number of endemic birds (349). Indonesia in turn is second in the world in the number of endemic mammals (165), leading all other countries in the number of endemic birds (356). The island of Madagascar has 67 endemic species of mammals, 97 endemic species of birds, 231 endemic species of reptiles and 142 endemic species of frogs and their relatives.



Sanjeeva Nayak

Figure 2 The island continent of Australia is particularly rich in the number of endemic groups. The distribution of this red kangaroo, along with many other species of marsupial mammals is restricted to Australia.

Figure 1 Biological treasure troves. Eighteen hot spots have been identified as regions on land that harbour a large number of species exclusive to the region and in great danger of extinction from human activities. This identification is however far from complete, and focuses on forests and Mediterranean scrublands and leaves out lakes, rivers and coral reefs. The Indian subcontinent includes two of these hot spots; namely, Western Ghats and Eastern Himalaya.



Sanjeeva Nayak

India has been christened one of the world's top twelve megadiversity nations.

Compare this with India, five times as large in land area, with 38 endemic species of mammals, 69 endemic species of birds, 156 endemic species of reptiles and 110 endemic species of frogs and their relatives.

A Megadiversity Country

On the world stage India is one of the richest nations in terms of biological diversity (*Figures 3 and 4*). We owe this to India's position in the tropical, subtropical latitudes with their inherent wealth of life. We owe this to the mountain chain of Himalaya that has created a great range of environmental regimes on the northern border, and the Thar desert that has created another gradient of rapid environmental change in the northwest. We also owe this to our possession of islands like Andamans, Nicobars and Lakshadweep with their own sets of endemic species. We owe this to India's position near the tri-junction of Eurasia, Southeast Asia and Africa. India has therefore been christened one of the world's top twelve megadiversity nations.

India supports 15000 species of flowering plants, 5000 of them exclusive to us. In contrast, Brazil the world's richest has 55,000 species of flowering plants; amongst our Asian neighbours China

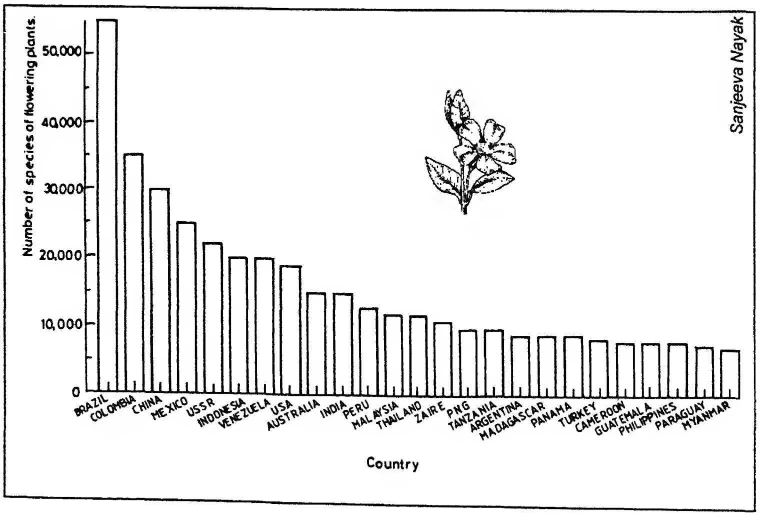


***Figure 3** Brazil with its extensive tracts of tropical rain forests leads the world, while India ranks 10th in the total number of flowering plants.*

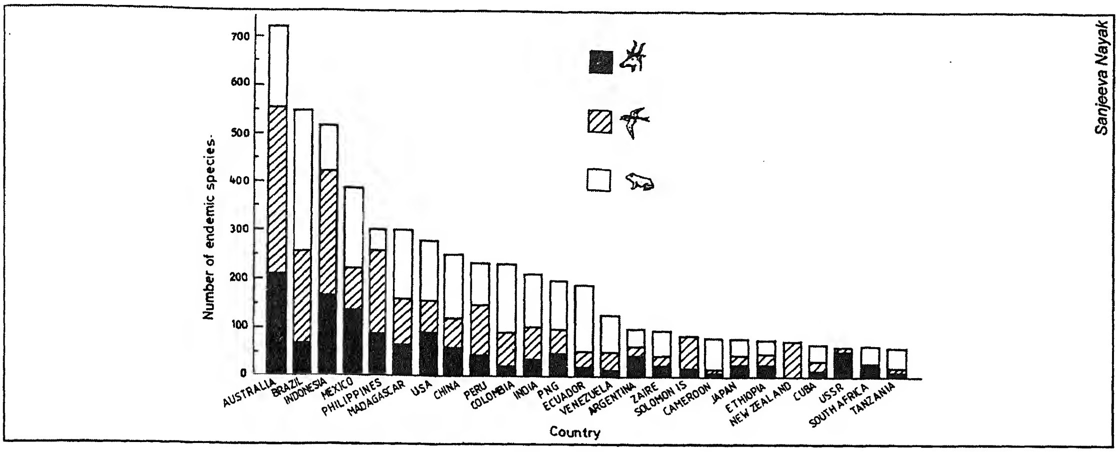


***Figure 4** The island continent of Australia leads the world, while India ranks 11th in the total number of endemic species of amphibians, birds and mammals.*

has 30,000 and Indonesia 20,000. India has 317 species of mammals, 38 of them exclusive to us. Indonesia leads the world with 515, 165 of them endemic, with both China and Brazil having 394 each. India has 969 species of birds, 69 of them endemic. The central American nation of Colombia leads the world with 1721 species; Indonesia has 1519 and China 1100. India has 389 species of reptiles, 156 exclusive to us, Mexico leads the world with 717, with 368 endemic; but as many as 616 of Australia's 700 species of reptiles are exclusive to that island continent. Of our neighbours Indonesia has 511 and China 282 species of reptiles. India does relatively well in terms of frogs, salamanders and their kith and kin. We have 206 species of amphibians, 110 of them endemic. Brazil is way ahead with 502, with 294 of them being endemic. Indonesia has 270 with 100 endemics and China 190 with 131 endemics.

That is where India stands, quite high in the wealth of total number of living species; although not at the very top. Overall we are close to the tenth in the pecking order of biodiversity of nations. Within the country too diversity of species is not evenly distributed. Parts of the country are especially rich due to a variety of natural causes; others less so. On top of that, of course, some parts have been secondarily enriched, or more often impoverished by human intervention. As mentioned above, two of India's great mountain ranges, Eastern Himalaya and the

Eastern Himalaya and the Western Ghats have been designated two of the world's eighteen hotspots of biodiversity.

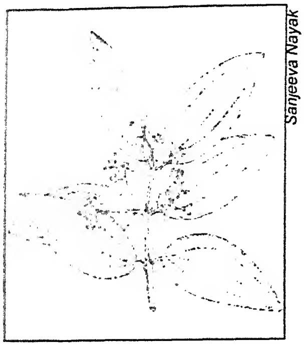


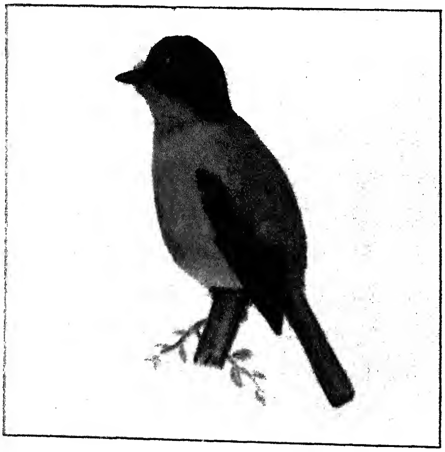
Figure 5 The hill chain of Western Ghats is particularly rich in spice plants. One such is Cinnamomum sulphoratum restricted to this part of the world.

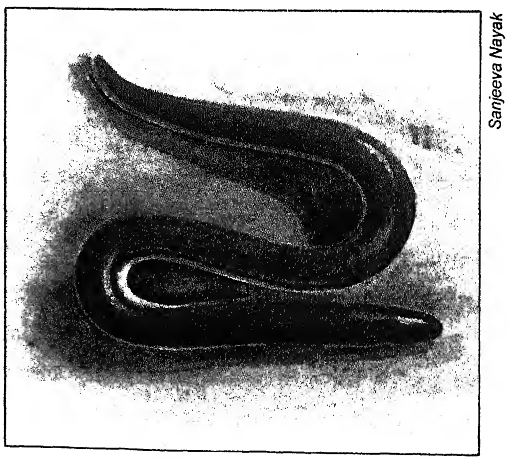
Western Ghats have been designated two of the world's eighteen hotspots of biodiversity. They qualify for this honour by virtue of the fact that Eastern Himalaya has some 3500 endemic species of higher plants, 20 endemic species of reptiles, 25 endemic species of amphibians; while the Western Ghats have 1600 endemic species of flowering plants, 7 endemic species of mammals, 91 endemic species of reptiles, 84 endemic species of amphibians (*Figures* 5, 6 *and* 7). Furthermore, as far as India is concerned it shares many of the species endemic to Eastern Himalaya with other countries, especially Nepal, Bhutan, China and Myanmar. From that perspective then the Western Ghats whose species are shared only with Sri Lanka are for us very much the most significant region from the perspective of biological diversity. Andaman and Nicobar islands are the third most significant area with 144 species of flowering plants and 75 species of land snails occurring nowhere else in the world.

To what degree does India share its wealth of living diversity with other countries? Some clues may be obtained by looking at waterbirds, perhaps the best known group of all organisms.

Figure 6 (bottom left) The sprightly black and orange flycatcher is endemic to Western Ghats.

Figure 7 (bottom right) Western Ghats and Sri Lanka constitute the centre of diversification of legless amphibians or caecilians. This species, Ichthyophis beddomei is restricted to the Western Ghats.





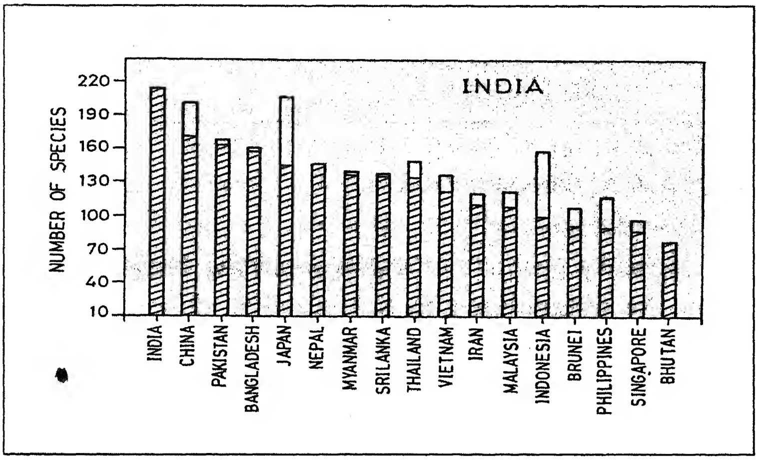


Figure 8 The total numbers of waterbird species and species shared (cross-hatched) with India amongst India's 16 Asian neighbours.

Regular censuses of waterbirds have been held every year in most Asian countries since 1987. These provide excellent information on the distribution of 326 species of such birds in 17 Asian countries. India harbours the largest number, 213 of these 326 species, Japan comes next with 206, landlocked Bhutan has the smallest number, 80. *Figure 8* shows the total number of species present in these 17 countries and the number of species shared with India. As might be expected, of all its neighbours, India has the largest proportion of species present in Bhutan; while China leads our neighbours in the number of Indian species present in that country.

China leads our neighbours in the number of Indian species present in that country.

Suggested Reading

- V H Heywood (Ed.) *Global Biodiversity Assessment.* United Nations Environment Programme. Cambridge University Press, Cambridge. pp. 1140, 1995.
- World Conservation Monitoring Centre . *Global Biodiversity : Status of the Earth's Living Resources.* Chapman and Hall, London. pp.585, 1992.

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In *Scientific American,* 1940 ... The frontiers of visibility have been pushed to an ever greater distance with the development of the electron microscope. (From *Scientific American,* September 1995)

Introduction to Algorithms

4. Turtle Graphics

R K Shyamasundar

R K Shyamasundar is Professor of Computer Science at TIFR, Mumbai and has done extensive research in various foundation areas of computer science.

The primary purpose of a programming language is to assist the programmer in the practice of her art. Each language is either designed for a class of problems or supports a different style of programming. In other words, a programming language turns the computer into a 'virtual machine' whose features and capabilities are unlimited. In this article, we illustrate these aspects through a language similar to *logo*. Programs are developed to draw geometric pictures using this language.

Programming Languages

A programming language is more than a vehicle for instructing existing computers. It primarily assists the programmer in the most difficult aspects of her art, namely program design, documentation and debugging. In other words, a good programming language should help express how the program is run, and what it intends to accomplish. It should achieve this at various levels, from the overall strategy to the details of coding and data representation. It should help establish and enforce programming disciplines that ensure harmonious cooperation of the parts of a large program developed separately and finally assembled together. It must assist in developing and displaying a pleasant writing style. In a broader sense, a programming language transforms the underlying machine into a *'virtual machine'* at a different level. The features and the capabilities of the virtual machine are limited only by the imagination of the language designer; of course, the virtual machine should in fact be efficiently 'implementable'. Ease of reading of programs is much more important than ease of writing.

A programming language primarily assists the programmer in program design, documentation and debugging.

In the previous articles of this series, we have looked at the basic control structures of languages. In this article, we shall take a look at an integration of such structures with simple graphic commands and illustrate how such an integration aids the programmer to solve problems in *turtle-geometry*. Finally, we provide a glimpse of a few of the programming languages that support different styles of programming.

A good programming language should help express how the program should run, and what it intends to accomplish.

A Simple Programming Language

First let us try to write algorithms to draw graphical (geometric) pictures using the following Turtle-like (Logo-like) commands. The Turtle-commands are used with the basic control structures such as sequencing, test and iteration described in earlier parts of the series.

Capabilities of Turtle

Let us first enumerate the basic capabilities of our Turtle:

- The Turtle moves on a plane.
- It starts at a coordinate point and has a direction.
- It can move from one point to another with or without drawing a line as it moves.
- It can rotate clockwise or anti-clockwise while remaining at the same point.

With such primitive capabilities, we can build the basic commands as shown in *Table 1*.

Table 1 Basic Commands for the Turtle

line n	Move n units and draw a straight line in the direction of the Turtle
skip n	Move n units in the direction of the Turtle without drawing a line
anti-clock n	Rotate the Turtle by n degrees in the anti-clockwise direction
clockwise n	Rotate the Turtle by n degrees in the clockwise direction

Programming Notation

As elaborated in the earlier articles, algorithms must be written in an unambiguous formal way. Algorithms intended for automatic execution by computers are called *programs* and the formal notations used to write *programs* are called *programming languages*. The concept of a programming language has been around since the mid-fifties. In 1945, the German mathematician Konrad Zuse invented a notation called Plankalkül. Statements in the language had a two-dimensional format: variables and their subscripts were aligned vertically and operations on them were laid out along the horizontal axis. Zuse wrote Plankalkül programs on paper including one that made simple chess moves. Even though the language was not implemented, many of the ideas developed by Zuse have been introduced in subsequent programming languages.

Drawing a Square

An algorithm to draw a square using the turtle-commands (essentially the way we draw a square) is shown in *Table 2*. Note that from the initial value of i and the termination condition of the loop (i.e., $i >$ 0 is false), we can conclude that four lines have been drawn. From the sequencing of the commands for rotation, we can deduce that the figure should be a square.

To draw a square of length 10 units one writes the command:

call square (10)

The above command draws the square shown in *Figure 1(a)*.

Drawing Regular Polygons

In the procedure for drawing a square, we have used "length" to be the *formal parameter*. Now, if we allow the number of sides to

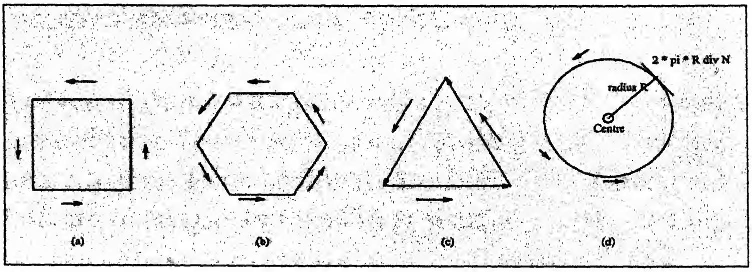

Figure 1 Polygons Drawn

RESONANCE
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Table 2 Drawing a square

```
procedure square (length:integer);
        i:= 4;
        while i > 0 do
                line length;        (* Draw a line *)
                anti-clock 90;      (* Rotate by 90 in the anti-clockwise direction *)
                i:= i -1
        end;                        (* 4 lines have been drawn *)
endprocedure
```

be another parameter then we can easily get polygons . In other words, we have refined further the procedural abstraction of the *square*; that is, square becomes a particular polygon; but not the other way. The procedure shown in *Table 3* draws a polygon of N sides of length L. As our turtle draws in "integer" steps, we should use such Ns as divide 360 exactly so that the polygon is a *closed* (beginning and end-points coincide) figure. Thus the commands

call polygon (6, 13) and call polygon (3,10)

draw a hexagon with sides of length 13 units and an equilateral triangle with sides of length 10 units respectively.

• Drawing a Circle

We can draw a circle by noting the fact that a circle can be approximated as a regular polygon with a large number of sides. For example,

call polygon (60, 8)

will draw a polygon of 60 sides with each of length 8 units, and will look like a circle on most computer screens! The usual way of drawing a circle is to draw it with a given radius, say R. To draw in such a way, one could draw a polygon of radius R around a centre point. A way to draw a circle of radius R, around a centre C, would be to draw N sides, each time starting from the centre, jumping to the edge, drawing a side and then jumping back to the centre again.

Note

- The assumption that the Turtle is oriented is important. Depending on its orientation, the line is drawn.
- The reader should understand the use of *parameters* discussed in the previous article of this series.

Table 3 Procedure for Drawing a Polygon

```
procedure polygon (N:integer, L:integer);
        i:= N;
        while i > 0 do
                line L;
                anti-clock (360 ÷ N);
                i:= i – 1
        endwhile
endprocedure
```

To be able to draw the circle using the method outlined, we need to use a command described earlier (but not used so far): *skip from one point to another point without drawing a line*. To recollect, the command and its effect are given in *Table 4*.

Table 4
SKIP Command

skip *n* – The turtle moves n units from the current position in the direction pointed by the turtle, without drawing a line.

skip –*n* – The turtle moves *n* units from the current position in the direction opposite to that pointed by the turtle, without drawing a line.

Let us see how we can devise an algorithm for drawing a circle using such an approach. Now, we know that the circumference of a circle of radius R is equal to 2π R. As our turtle moves in integer units, we shall approximate π by 3. Thus, the length of the side becomes (2 * 3 * radius) ÷ sides. A procedure implementing these ideas is described in *Table 5*.

Exercise: Are there any drawbacks of the approximation used?

The start and end-points may not coincide! However, the centre of the circle will be where it was intended to be. It may also be observed that the *skip*-command is somewhat independent of other commands. One of the interesting questions often raised is the independence (or orthogonality) of basic commands and constructs from various considerations. Some of these aspects will be featured in future articles.

Table 5 Procedure for Drawing a Circle

```
procedure circle (sides:integer, radius:integer);
    i:=1;
    while i ≤ sides do
                skip radius;
                clockwise 90;
                skip ( – (3 * radius ÷ sides);
                line (2 * 3 * radius ) ÷ sides;
                skip (– (3 * radius) ÷ sides);
                anti-clock 90;
                skip (– radius);
                clockwise (360 ÷ sides)
                i:= i+1
    endwhile
endprocedure
```

Complex Patterns

Let us consider the problem of drawing a simple flower which consists of a number of petals. For simplicity, let us assume that the petal has a simple shape as shown in *Figure 2(a)*.

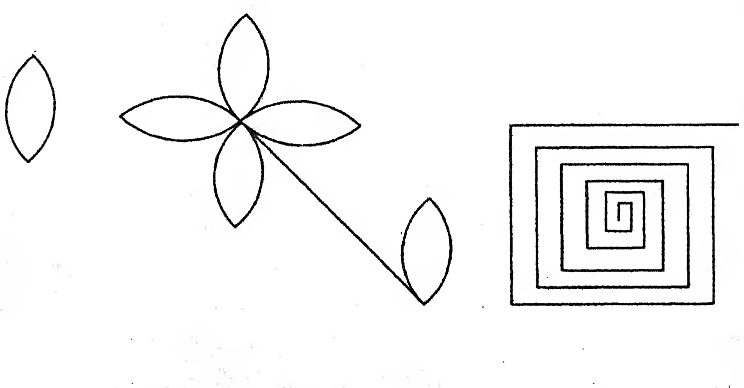
(a) Petal (b) Flower (c) Spiral

Figure 2 Patterns

Turing Award

The Turing Award — highest award in Computer Science — is presented annually "to an individual selected for contributions of a technical nature to the computing community that are judged to be of lasting and major importance to the field of computing science." The award commemorates Alan M Turing, an English mathematician whose work "captured the imagination and mobilized the thoughts of a generation of scientists" to quote Alan J Perlis, the first recipient of the award.

Programming is fundamental to the computing field. Programs play a dual role both as the notations that influence thought and also the directions for an abstract computing machine. The influence can be seen by the fact that in the first 20 years half of the Turing awards have recognized contributions to programming languages, programming methodology, and programming systems. The award lectures by Alan J Perlis, Edsgar W Dijkstra, Donald E Knuth, Dana Scott, Michael Rabin, John Backus, Robert Floyd, C A R Hoare, Ken Thompson, Dennis Ritchie and Niklaus Wirth provide insights into the various computational aspects as seen by the pioneers.

○ Drawing a Petal

We have shown above how we can draw circles and arcs. Using the same technique, it should be easy to arrive at a procedure to draw a petal. For simplicity, the reader can think of a petal as made up of two quadrants of a circle with some radius, say size. Since the orientation of the turtle is important, let us enforce the condition that the turtle returns to its original position and orientation after the petal is drawn. Let us denote the procedure by

procedure PETAL (SIZE: integer)

The code for this procedure is left as an exercise to the reader. Now, a command of PETAL (5) will draw a petal similar to that shown in *Figure 2(a)* with 5 units as the radius. Now, we can program a simple flower using PETAL as a procedure. Let us assume that a flower has a head, with several petals in a circle, and a stem with a leaf, which looks just like a petal. A program to draw a flower with N petals of size S is shown in *Table 6*.

One can draw spirals of various shapes and sizes

Table 6 Drawing a Flower

```
procedure FLOWER (N: integer; S: integer)
    i:= 0;
    while i < N do
        call PETAL (S);         (* draw a petal of size S *)
                                (* as per assumption the turtle returns to its initial
                                   position on completion *)
        anti-clock ((360 ÷N)); (* Rotate the turtle for the next petal*)
        i:=i+1;
    end;
    anti-clock 180;             (* turn the direction of the turtle*)
    line (4 * S);               (* draw a stem of length equal to 4 times the size
                                   of the petal *)
    anti-clock 90;              (* position the turtle for the leaf *)
call PETAL (S)
endprocedure
```

Using the above procedures, the user can create further patterns such as a bunch of flowers etc.

Drawing a Rectangular Spiral Pattern

One can draw spirals of various shapes and sizes. Consider the shape shown in *Figure 2(c)*. The growing spiral could be considered as made up of lines and rotations on the turtle position which is captured in the program shown in *Table 7*. Now a program to draw a spiral is shown in *Table 8* which uses the procedure STEP given in *Table 7*. Size 1 and size 2 indicate the lengths of the least and the maximum sides in the spiral respectively.

```
procedure STEP (size:integer, angle: integer);
    line size;
    clockwise angle;
endprocedure
```

Table 7 Basic Step in a Spiral

Table 8 Program for Drawing a Spiral

```
procedure SPIRAL (size 1, size 2: integer, angle:integer);
    i:=1;              (* used for the offset from side to side*)
                        (* assumed to be 1 here *)
    if size 1 < size 2 then
        call STEP (size 1, angle);
        size 1:= size 1+i; (* increment the side of the spiral *)
        call SPIRAL (size 1, size 2, angle); (* a recursive call *)
    end
endprocedure
```

Exercise

1. Try and trace the above procedure with some values for the parameters; this will give you a good understanding of the recursive program structure and the correspondence between formal and actual parameters.
2. The interested reader may write a program to generate logarithmic spirals.

It may be noted that the program for drawing a spiral is recursive.

It may be noted that the program for drawing a spiral is recursive; in a sense, it is natural to treat it as a recursive program; by removing the part in the beginning or at the end, the pattern remains a spiral. In fact, the program reflects a growing spiral. That is, it starts from a basic step and adds to it in stages. It is also possible to write it in the reverse manner. An iterative program for the spiral is shown in *Table 9*. Iteration and recursion are two powerful techniques of programming; a comparative view would be presented in the forthcoming articles.

Fractals

A fractal is a geometric figure in which an identical motif repeats itself on an ever diminishing scale. Benoit B Mandelbrot, a French-American mathematician, is the godfather of fractals.

```
procedure SPIRAL (size 1, size 2: integer, angle:integer);
        i:=1;            (* used for the offset from side to side*)
                                  (* assumed to be 1 here *)
while  size 1 < size 2  do
        call STEP (size1, angle);
        size1:= size1+i;  (* increment the side of the spiral*)
end
endprocedure
```

Table 9 An Iterative Program for Drawing a Spiral.

The extraordinary visual beauty of fractal images has made these endlessly repeating geometric figures widely familiar. They are more than just appealing visual patterns or simply part of pure mathematics and have proved to have a wide range of uses (widely used in chaos theory *Resonance*, Vol 1, No 5). Once they were just mathematical curiosities; the advances in computer technology have made it possible to generate these patterns on even simple computers. In *Figure 3*, we illustrate a simple fractal (referred to as H-fractal) which can be programmed in the language discussed above.

The H-fractal is called a dendrite after the Greek dendron, tree.

The H-fractal shown (arrows at the middle show one symmetry point) is called a dendrite after the Greek dendron, tree. The

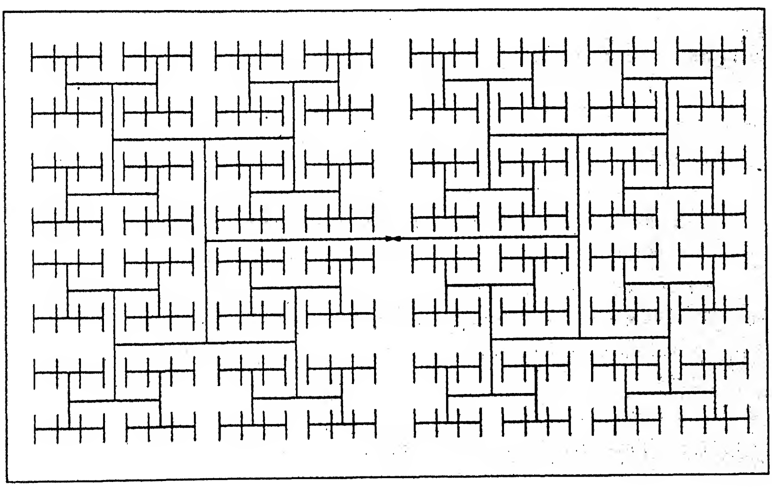

Figure 3 H - Fractal

figure is singly-connected (with a single cut it becomes two figures not connected by any line). The structure is really like that of a tree. A trunk separates into two side branches, each of which acts as a trunk for the following two smaller side branches, and so on. Writing a program to generate such a figure will show the power of recursion as well.

There has been a spectrum of programming languages catering to various styles and purposes.

Discussion

We have illustrated, using a turtle-like language, how one can arrive at a language for drawing geometric figures. The programmer visualizes a *virtual machine* of turtle-geometry using a system with a turtle-language translator. To regard the notations of programming as *languages* is a mixed blessing. On the one hand it is very helpful from the point of view that it provides a natural framework and terminologies such as *grammar*, *syntax* and *semantics* in understanding the notation clearly. On the other hand, it must be pointed out that the analogy with so called 'natural languages' is misleading since natural languages which are non-formalized derive both their weakness and strength from their vagueness and imprecision. There has been a spectrum of programming languages catering to various styles and purposes. In future articles, we will provide an overview of the different styles after discussing data-structures in the development of algorithms.

Suggested Reading

- **ACM Turing award lectures: the first twenty years: 1966- 1985, NewYork: ACM Press, Addison-Wesley, 1987. This book gives an insight into the views of the pioneers on computation and programming of computer science.**
- **S Papert. *Mindstorms: Children, Computers and Powerful ideas.* Harvester Press, Breighton. 1980.**
- **H Abelson and A di Sessa. *Turtle Geometry: The computer as a medium for exploring mathematics.* M.I.T. Press, Cambridge, Mass. 1981.**
- **H Lauwerier. Fractals: Images of Chaos. Penguin Books. 1991. This book introduces fractals to a wide audience.**

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Learning Organic Chemistry Through Natural Products

5. A Practical Approach

N R Krishnaswamy

N R Krishnaswamy was initiated into the world of natural products by T R Seshadri at University of Delhi and has carried on the glorious tradition of his mentor. He has taught at Bangalore University, Calicut University and Sri Sathya Sai Institute of Higher Learning. Generations of students would vouch for the fact that he has the uncanny ability to present the chemistry of natural products logically and with feeling.

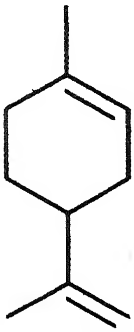
In this article details for the isolation of natural products are described.

In parts 1-4 of this series, an approach to the chemistry of natural products was delineated covering a fairly wide range of aspects. The learning process could be made more interesting through demonstrations and experimentation by the students themselves. The former could be incorporated within the classroom lectures whereas the latter could form part of the laboratory curriculum. In part 1 of the series, a simple thin-layer chromatographic experiment was demonstrated. In this article we describe the procedures for the isolation of some natural products. Many simple experiments using the isolated molecules that can be demonstrated in the classroom are also discussed.

Students should be encouraged to analyse the chemical components of a specimen like a seed, bark, flower, root or a lichen (*Box 1*) which may draw their attention because of a distinctive colour or smell or some other characteristic. I recall the advice given to students of natural products chemistry by the New Zealand chemist L H Briggs, "Carry a pair of scissors, a pen-knife and a few polythene bags so that you can collect interesting

Box 1

Lichens (*pron.*liken) are symbiotic organisms consisting of tiny fungi and equally tiny algae. The two live together so closely and intimately that they appear as a single organism. Lichens can be found on trees, rocks and ancient monuments such as the Angkor Vat of Kampuchea. A species of the lichen *Parmelia* is commonly seen in Bangalore as pale green patches on trees and rocks. It is believed that the Biblical manna was a lichen.



Limonene

species when you go for a walk or are on a tour." The teacher should also build up a collection of the natural products, included in the syllabus, to be shown to the students. New additions could be continuously made and these can ultimately go into a permanent collection. It is easy to procure samples of terpenoids like geraniol, linalool, limonene, menthol, pinene, camphene and camphor, the alkaloids such as nicotine, piperine, codeine and quinine, and flavonoids like quercetin, kaempferol, their glucosides and cyanidin chloride. Similarly, samples of some of the carotenoid pigments like lycopene, beta-carotene and bixin can also be readily obtained. Some of these compounds can be isolated in the laboratory without any sophisticated instrument or apparatus.

Isolation of Limonene and Hesperidin from Orange Peels

Dry orange peels in the shade by spreading them out on a table. Cut them into small bits and pack them in a Soxhlet extractor. Extract the material with light petrol (petroleum ether boiling at 40 – 60°C) till the siphoned material is colourless. Remove the solvent by distillation on a water-bath and distil the residue under reduced pressure. Limonene distils over as a colourless liquid at 75°C at 27 mm pressure. Alternatively, subject fresh orange peels to steam distillation and separate the essential oil distilling over. Dry the oil over anhydrous sodium sulphate and distil to obtain pure limonene (*Box 2*). 100 grams of the crude essential oil yields on the average, 75 grams of pure limonene.

Box 2

(+) Limonene occurs in orange and lemon oils. The (-) form is present in the oil of peppermint whereas the racemic form, also known as dipentene, can be obtained from turpentine oil. (+) Limonene can be converted via its nitroso-chloride into (-) carvone.

After the orange peels have been completely de-fatted, extract the material remaining in the Soxhlet extractor with methanol till the siphonings are colourless. Concentrate the extract under reduced pressure and re-crystallise the syrupy residue from aqueous acetic acid. The flavonoid glycoside, hesperidin, separates out as colourless needles, m.p. 252 – 254°C. The compound gives a wine-red colour with alcoholic ferric chloride and bright violet colour in the Shinoda test (*Box 3*). To perform the Shinoda test

add a pinch of magnesium powder to a solution of the compound in alcohol. Add concentrated HCl in drops and observe the colour formed.

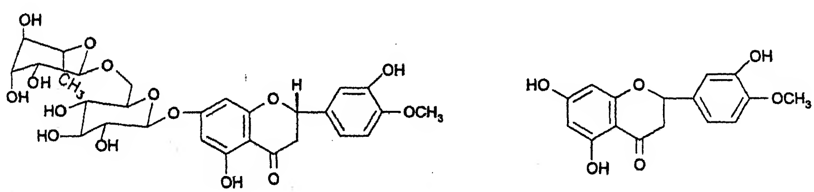
Hydrolysis of Hesperidin: Paper Chromatographic Identification of the Sugars and Isolation of the Aglycone (hesperetin)

Dissolve 1 g of hesperidin in 20 ml of ethylene glycol containing 1 ml of concentrated sulfuric acid and heat the mixture on a boiling water-bath for 40 – 45 minutes. Pour the clear yellow solution into 50 ml of water and cool. Collect the precipitated hesperetin (aglycone) on a Büchner funnel, wash it free of acid using ice-cold water, and recrystallise from ethanol. The pure aglycone separates out as crystals melting at 224 – 226°C (yield: 0.35 g). Observe the colours given by the compound with alcoholic $FeCl_3$ and Mg-HCl (Shinoda test).

Neutralise the filtrate remaining after the separation of hesperetin and concentrate it preferably under reduced pressure or in a porcelain dish on a water bath. Examine the syrupy liquid thus obtained by circular paper chromatography (*Box 4*) using n-butanol-acetic acid-water (4:1:5) as the developing solvent. Spray the developed paper with a solution made by mixing equal volumes of 0.5 N aqueous silver nitrate and 5 N aqueous ammonia. Dry the chromatogram at 100°C for ten minutes when you will notice two brown coloured rings appearing. Measure the R_f values and compare them with R_f values of common

Box 3

Colour reactions, though largely empirical in nature, are very useful in structural elucidations. They are widely used in studies on alkaloids, steroids and triterpenoids and flavonoids. The Shinoda test involves a reductive transformation of colourless or pale yellow coloured flavones and flavonols into deeply coloured products among which are anthocyanidins. Try to think of a possible mechanism for this reaction.



Hesperidin Hesperetin

monosaccharides for the same solvent system. The sugars in this case are glucose (R_f 0.29) and rhamnose (R_f 0.48).

Related Experiments

Make ethanolic extracts of the flowers listed below, concentrate the extracts and examine the residue by paper chromatography (circular and ascending or descending). View the developed chromatograms under ultraviolet light with and without exposure to ammonia. Spray the chromatograms separately with alcoholic ferric chloride and ethanolic aluminium chloride, and observe the number of rings or spots and the colour in each case. View the paper under UV light after spraying, and note if any fluorescent rings or spots are seen (*Box 5*). With each crude extract carry out the following colour reactions:

1. Colour with alcoholic ferric chloride.
2. Colour and fluorescence, if any, in concentrated sulfuric acid.
3. Play of colours, if any, with aqueous sodium hydroxide.
4. Colour with magnesium and HCl.
5. Colour with zinc dust and HCl
6. Colour with sodium amalgam before and after addition of HCl.

Make a careful record of the colours observed and draw appropriate conclusions in consultation with your laboratory instructor.

Following is the list of plants, the flowers of which can be easily procured and examined for their flavonoid compositions:

Box 4

Circular paper chromatography, also known as horizontal chromatography is a quick and convenient method of separation and analysis of mixtures of compounds such as the amino acids, reducing sugars and polyphenolics. No elaborate equipment is needed (a Petri dish with a glass plate as a cover will do) and the compounds appear as concentric rings which can be detected with the help of appropriate spraying agents.

Box 5

5-Hydroxyflavones form chelate complexes with aluminium chloride which exhibit bright yellow fluorescence under uv light. Several types of aromatic and hetero-aromatic compounds such as the polythienyls and coumarins exhibit fluorescence under uv light and can thus be readily detected on paper and thin-layer chromatograms. Synthetic coumarins are used as optical brighteners on account of this property.

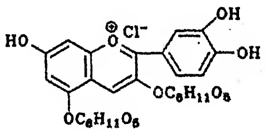
- *Gossypium indicum* (Cotton flower).
- *Argemone mexicana* (A plant with prickly leaves and bright yellow flowers) (*Box* 6).
- *Tagetes erecta* (marigold).
- *Chrysanthemum coronarium* (Samanthi).
- *Hibiscus esculentus* (Bindi) and other species of Hibiscus.
- *Butea frondosa* (flame of the forest).

Box 6

Most yellow and orange coloured flowers contain flavonols and their glycosides. Yellow and orange floral colours may also be due to the presence of chalcones, aurones, carotenoids and quinones.

Isolation of Cyanin Chloride from Red Roses

Collect fresh, deep-red coloured roses, cut them into small bits and soak them in methanol containing 10% HCl. After the petals are completely bleached, decant the clear solution and concentrate it, preferably under reduced pressure. Examine the concentrated solution of the anthocyanin pigment thus obtained by paper chromatography using butanol-acetic acid-water (4:1:5) (use both layers in separate experiments) and phenol-water as the developing solvents. Observe the number of rings (spots) and measure their R_f values. The major pigment is cyanin chloride. Keep the concentrated solution in a vacuum desiccator over concentrated sulfuric acid. Collect the crystals formed.



Cyanin chloride

Crude anthocyanin pigments of the following plant materials can also be similarly extracted and examined (*Box* 7).

- Flowers of Jacaranda, *Hibiscus Rosa sinensis* (Jabakusum), and other red, blue and purple coloured garden flowers.
- Berries of jasmine, coffee, black grapes and other dark coloured fruits.

Box 7

Deep orange, red, purple and blue coloured flowers are likely to contain anthocyanin pigments, many of which occur in nature as complexes with proteins and metals. During their isolation these complexes often break up and what are obtained are the simpler anthocyanins with different tinctorial properties.

Box 8

Natural bixin or labile bixin is a polyene in which one double bond has the *cis* configuration. It is a non-toxic, fat soluble pigment and is, therefore, used as a food colouring agent.

- Poinsettia leaves.

In each case, observe the colour on changing the pH of the solution from acidic to alkaline.

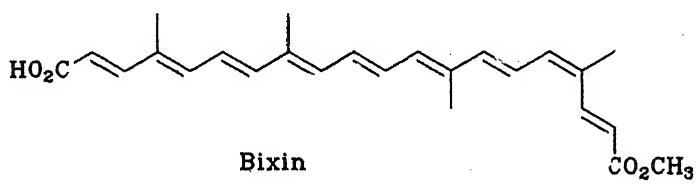
Isolation of a Carotenoid Pigment — Bixin from *Bixa orellana* (Annatto Seeds)

Boil whole seeds of *Bixa orellana* (do not powder!) with ethyl acetate. Decant the extract and concentrate it to less than half its volume. Collect the pure crystalline bixin which separates out on cooling the concentrated extract on a Büchner funnel (*Box 8*). The average yield is 1.1 g from 100 g of the seed. Pour the filtrate into light petrol when a deep-red coloured solid separates out. This is impure bixin. Purer bixin can be obtained by re-dissolving it in a minimum quantity of ethyl acetate and precipitating it by careful addition of light petrol. By this method another 0.7 to 0.8 g of pure bixin can be obtained. Pure bixin separates out from ethyl acetate – light petrol as deep red needles. It gives a blue colour with concentrated sulfuric acid. Its purity can be checked by TLC on silica gel using chloroform-methanol (94:6) as the developing solvent.

Box 9

The orange stalks of the flower heads of *Nyctanthes arbortrystis*, known in Sanskrit as the Parijatha flowers, contain carotenoid glucosides which are closely related to the pigments of *Crocus sativa* (saffron). Therefore, thinly sliced and dried parijatha flower stalks have been used to adulterate saffron. The parijatha flowers do not have the flavouring principles of saffron.

The carotenoid glycosides of the flowers of *Nyctanthes arbortrystis* (Parijatha) can be similarly extracted and examined. These compounds are derivatives of crocetin which is closely related to bixin (*Box 9*).



Bixin

Betanins from Bougainvillea

Immerse air dried bracts of coloured *Bougainvilleae glabra* in 1% methanolic HCl. After allowing the mixture to stand for a day, decant the coloured solution and add a second lot of fresh solvent to the once-extracted material. Concentrate the combined extract under reduced pressure. To the concentrated solution add a mixture of diethyl ether and light petrol (2:1 ratio) when the colouring matter separates. After a couple of hours, decant the supernatant liquid, re-dissolve the residue in 1% methanolic HCl and re-precipitate the pigments with ether-petrol. Repeat the process 5 to 8 times. Finally, dry the deep blue-red coloured viscous residue in a vacuum desiccator over calcium chloride. The dark purple coloured solid thus obtained is a mixture of betacyanins and betaxanthines.

Box 10

The colouring principles of Bougainvilleae resemble the anthocyanins and the flavonoids but they belong to a different chemical type. They are nitrogenous compounds biosynthetically produced from the amino acid proline. These compounds known as the betacyanins and betaxanthins are confined to the plant order Centrospermae and have considerable value as taxonomic markers. They are also present in beet root and Amaranthus.

Mandelonitrile from a Millipede – Comparison with a Synthetic Sample

With the help of an entomologist collect a few polydesmid millipedes (*Harpaphe haydeniana*) which are found in large numbers in areas dominated by deciduous trees (there are a large number of them in the Calicut University campus). Immobilise the millipedes by chilling them to 4°C (this can be done by keeping them in a petri dish inside the freezer compartment of a refrigerator). Then place them under boiling ethanol and crush them. Filter the extract, if necessary with the aid of Celite, and extract the residue a second time with boiling ethanol. Concentrate the combined extract under reduced pressure, add water and extract with ether in a separatory funnel. Use light petrol-methanol-carbon tetrachloride (125:50:50) as the developing solvent for the TLC examination of the crude mandelonitrile present in the ether extract. The compound has an R_f value of 0.5 in this solvent system and can be detected by spraying the TLC plates with 5% NaOH solution followed by a saturated solution of 2,4-dinitrophenylhydrazine in 6 M HCl (*Box 10*).

Compare the compound on TLC, with a sample of synthetic mandelonitrile prepared as follows :
In an 125 ml Erlenmeyer flask, dissolve 11 g of sodium hydrogen sulphite in 30 ml of water, add 10 ml of benzaldehyde, swirl and stir vigorously until the oily aldehyde is completely converted into the crystalline bisulphite adduct. Cool to room temperature, add a solution of 14 g of KCN in 25 ml of water (CAUTION: Since KCN is poisonous wear gloves and do this in a fume hood with proper ventilation) swirl and stir for about 10 minutes until all but a trace of the solid has dissolved. Mandelonitrile separates out as a thick oil. Pour the mixture into a separatory funnel, rinse the flask with small amounts of ether and water and shake the mixture vigorously for a minute to complete the reaction. Add 20 ml of ether, shake, pour off the aqueous layer down the drain (CAUTION: make sure that the sink does not have any acid, as this may cause the formation of poisonous HCN gas) and wash the ether layer with 25 ml of water. Dry the ether solution over anhydrous sodium sulphate and remove the solvent. Examine the residue by TLC.

Box 11

Mandelonitrile is detected on TLC plates as benzaldehyde as it is easily hydrolysed being a cyanohydrin. As a matter of fact, millipedes use it as a precursor for generating the toxic hydrogen cyanide.

Piperine from Black Pepper

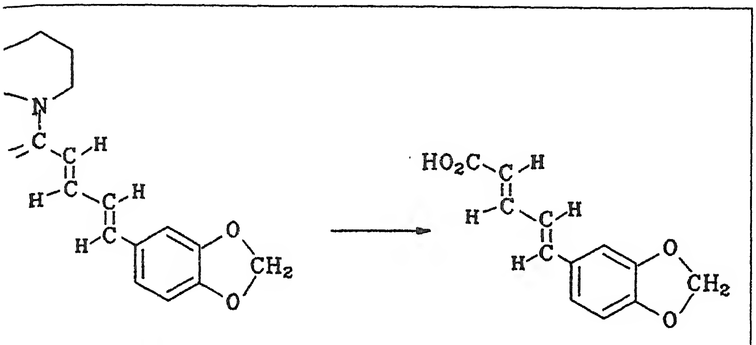
Grind 10 g of black pepper to a coarse powder and extract with 95% ethanol in a Soxhlet extractor. Concentrate the extract under reduced pressure on a water-bath at 60°C. Add 10 ml of 10% alcoholic KOH to the residue and allow the mixture to stand for a few minutes (*Box 12*). Carefully decant the supernatant solution from the solid deposit. When the alcoholic solution is left overnight, yellow-coloured needles separate out. The yield is 0.3g. Record the melting point (125 – 126°C) and the NMR spectrum of the compound.

Box 12

Piperine, being an amide, is a non-basic alkaloid and is the compound responsible for the pungency of black pepper.

Hydrolysis of Piperine – Isolation of Piperic Acid

Reflux a solution of 1 g of piperine in 10 ml of 10% ethanolic KOH for 90 minutes. Evaporate the solution to dryness by



Piperine Piperic Acid

stillation under reduced pressure, the receiver being cooled in ı ice-salt bath. Suspend the solid potassium piperinate remaining the distillation flask in hot water and add concentrated HCl. ›llect the yellow precipitate, wash it with ice-cold water and re-ystallise it from ethanol. Pure piperic acid is obtained as yellow :edles, m.p. 216 – 217°C. Saturate the distillate (in the receiver) .th HCl and evaporate it to dryness when piperidine ·drochloride separates out. Re-crystallise it from ethanol. Pure peridine hydrochloride has a m.p. 244°C.

ıggested Reading

- *Natural Products - A laboratory guide* by R Ikan. Academic Press. 2nd Edition.
- Fieser and Fieser. *Organic Experiments*. p.110, 1965.

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Max Planck on a New Scientific Truth..."Max Planck surveying his own career in his 'Scientific Autobiography' sadly remarked that a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up, that is familiar with it." (From *The Structure of Scientific Revolutions* by Thomas S Kuhn)

Planets Move in Circles !

A Different View of Orbits

T Padmanabhan

T Padmanabhan works at the Inter University Centre for Astronomy and Astrophysics (IUCAA) at Pune. His research interests are in the area of cosmology, in particular the formation of large scale structures in the universe, a subject on which he has written two books. The other area in which he works is the interface between gravity and quantum mechanics. He writes extensively for general readers, on topics ranging over physics, mathematics, and just plain brain teasers.

The orbits of planets, or any other bodies moving under an inverse square law force, can be understood with fresh insight using the idea of velocity space. Surprisingly, a particle moving on an ellipse or even a hyperbola still moves on a circle in this space. Other aspects of orbits such as conservation laws are discussed.

Yes, it is true. And no, it is not the cheap trick of tilting the paper to see an ellipse as a circle. The trick, as you will see, is a bit more sophisticated. It turns out that the trajectory of a particle, moving under the attractive inverse square law force, is a circle (or part of a circle) in the *velocity space* (The high-tech name for the path in velocity space is *hodograph*). The proof is quite straightforward. Start with the text book result that, for particles moving under any central force $f(r)\,\hat{\mathbf{r}}$, the angular momentum $\mathbf{J}=\mathbf{r}\times\mathbf{p}$ is conserved. Here $\mathbf{r}$ is the position vector, $\mathbf{p}$ is the linear momentum and $\hat{\mathbf{r}}$ is the unit vector in the direction of $\mathbf{r}$. This implies, among other things, that the motion is confined to the plane perpendicular to $\mathbf{J}$. Let us introduce in this plane the polar coordinates $(r, \dot{\theta})$ and the cartesian coordinates (x, y). The conservation law for $\mathbf{J}$ implies

$$\frac{d\theta}{dt} = \text{constant}/r^2 \equiv hr^{-2}, \tag{1}$$

which is equivalent to Kepler's second law, since $(r^2\dot{\theta}/2)= h/2$ is the area swept by the radius vector in unit time. Newton's laws of motion give

$$m\frac{dv_x}{dt} = f(r)\cos\theta;\; m\frac{dv_y}{dt} = f(r)\sin\theta\,. \tag{2}$$

Dividing (2) by (1) we get

$$m\,\frac{dv_x}{d\theta} = \frac{f(r)\,r^2}{h}\cos\theta;\; m\,\frac{dv_y}{d\theta} = \frac{f(r)\,r^2}{h}\sin\theta\,. \qquad (3)$$

The high-tech name for the path in velocity space is *hodograph.*

The miracle is now in sight for the inverse square law force, for which $f(r)\,r^2$ is a constant. For planetary motion we can set it to $f(r)\,r^2 = -GMm$ and write the resulting equations as

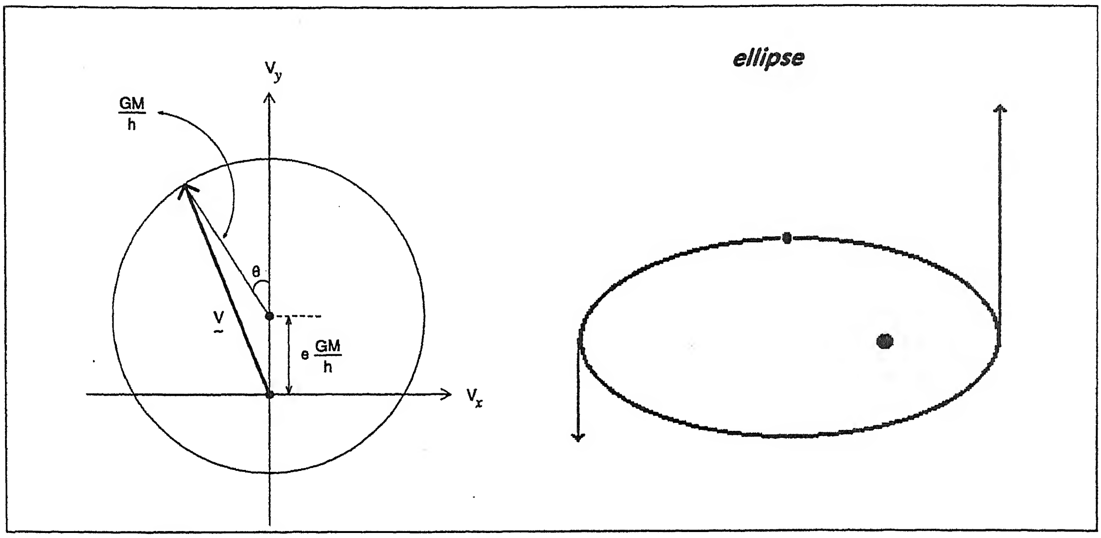
$$\frac{dv_x}{d\theta} = \frac{-GM}{h}\cos\theta;\; \frac{dv_y}{d\theta} = \frac{-GM}{h}\sin\theta\,. \qquad (4)$$

Integrating these equations, with the initial conditions $v_x\,(\theta=0) = 0$; $v_y\,(\theta = 0) = u$, squaring and adding, we get the equation to the *hodograph*:

$$v_x^2 + (v_y - u + GM/h)^2 = (GM/h)^2 \qquad (5)$$

which is a circle with center at $(0, u - GM/h)$ and radius GM/h. So you see, planets do move in circles!

Some thought shows that the structure depends vitally on the ratio between u and GM/h, motivating one to introduce a quantity e by defining $(u - GM/h) \equiv e\,(GM/h)$. The geometrical meaning of e is clear from *Figure 1*. If $e=0$, i.e, if we had chosen the initial conditions such that $u = GM/h$, then the center of the hodograph is at the origin of the velocity space and the magnitude of the velocity remains constant. Writing $h=ur$, we get $u^2 = GM/r^2$ leading to a circular orbit in the real space as well. When $0<e<1$, the origin of the velocity space is inside the circle of the hodograph. As the particle moves the magnitude of the velocity changes between a maximum of $(1+e)\,(GM/h)$ and a minimum of $(1-e)\,(GM/h)$. When $e=1$, the origin of velocity space is at the circumference of the hodograph and the magnitude of the velocity vanishes at this point. In this case, the particle goes from a finite distance of closest approach, to



infinity, reaching infinity with zero speed. Clearly, $e = 1$ implies $u^2 = 2GM/r_{initial}$ which is just the text book condition for escape velocity and a parabolic orbit.

Figure 1 Velocity Space: The x and y components of the velocity vector v are plotted. The origin represents zero velocity, and the circle gives the velocity of the planet at different times i.e it is the orbit in velocity space. The radius vector in real space is parallel to the tangent to this circle, because changes in velocity are parallel to the force which is central. The angle θ turned by the tangent is thus the same as that turned by the radius vector. Real space orbit at top right.

When $e > 1$, the origin of velocity space is outside the hodograph and *Figure 2* shows the behaviour in this case. The maximum velocity achieved by the particle is OB when the particle is at the point of closest approach in real space. The asymptotic velocities of the particle are OA and OC obtained by drawing the tangents from O to the circle. From the figure it is clear that $\sin \phi = e^{-1}$. During the *unbound motion* of the particle, the velocity vector traverses the part ABC. It is circles all the way! (Incidentally, can you find a physical situation in which the minor arc AC could be meaningful?)

Given the velocities, it is quite easy to get the real space trajectories. Knowing $v_x(\theta)$ and $v_y(\theta)$ from (4) one can find the kinetic energy as a function of θ and equate it to $(E+GMm/r)$, thereby recovering the conic sections. Except that, there is a more elegant way of doing it.

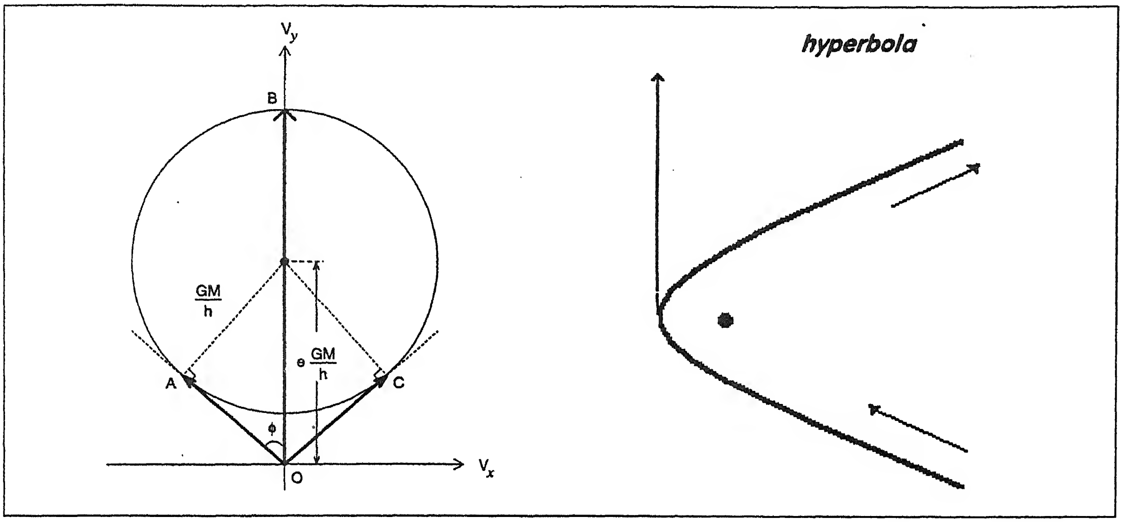


Figure 2 Velocity space representation of a hyperbolic orbit. Note that the origin is now outside the circle. Only the arc ABC is traversed. OB is the maximum velocity, attained at closest approach, 2ϕ is the angle of scattering. Real space orbit shown at right.

There is a theorem proved by Newton through (rather than *in*) Principia, which states that 'anything that can be done by calculus can be done by geometry' and our problem is no exception. The geometrical derivation is quite simple: In a small time interval δt, the magnitude of the velocity changes by $\Delta v = \hat{r}\,(GM/r^2)\,\delta t$ according to Newton's law. The angle changes by $\Delta\theta = (h/r^2)\,\delta t$ from the conservation of angular momentum. Dividing the two relations, we get

$$\frac{\Delta|v|}{\Delta\theta} = \frac{GM}{h} \tag{6}$$

But in velocity space Δv is the arc length and $\Delta\theta$ is the angle of turn and if the ratio between the two is a constant, then the curve is a circle. So there you are.

To get the real space trajectory from the hodograph, we could reason as follows: Consider the transverse velocity v_T at any instant. This is clearly the component perpendicular to the instantaneous radius vector. But in the central force problem, the velocity change Δv is parallel to the radius vector. So v_T is also perpendicular to Δv; or in other words, the v_T must be the

component of velocity parallel to the radius vector in the velocity space. *Voila!* From *Figure 1*, it is just

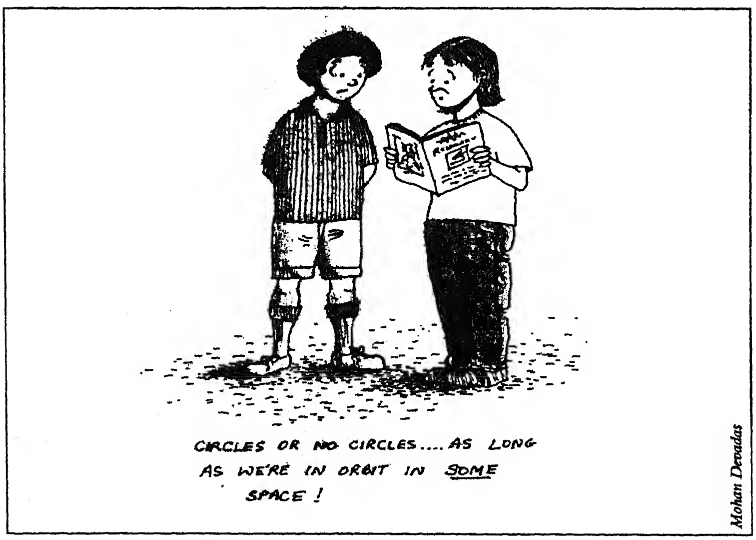
$$v_T = \frac{GM}{h} + \frac{GM}{h}\, e \cos\theta = \frac{GM}{h}\,(1+e\cos\theta) = \frac{h}{r} \qquad (7)$$

with the last relation following from the definition of angular momentum. One immediately sees the old friend — the conic section — with a latus rectum of $l=h^2/GM$ and eccentricity of e (Good we didn't denote the ratio between $(u - GM/h)$ and (GM/h) by k or something!).

There is a theorem proved by Newton through (rather than in) Principia, which states that 'anything that can be done by calculus can be done by geometry'

The elegance of geometry over calculus in the above analysis (or anywhere for that matter, though lots of people disagree) is a bit fake with calculus entering through the back door. But even with calculus, the more general way to think about the Kepler problem is as follows. For any time-independent central force, we have constancy of energy E and angular momentum $\mathbf{J}$. Originally, a particle moving in 3 space dimensions has a phase space[1] which is 6 dimensional. Conservation of the four quantities (E, J_x, J_y, J_z) confines the motion to a region of $6-4=2$ dimensions. The projection of the trajectory onto the xy-plane will, in general, fill

[1] This is a space obtained by combining the three coordinates xyz with three momentum components mv_x, mv_y, $m\,v_z$. This is a good way of describing the current state of the system, since one can use this information to predict the future.



a two-dimensional region of space. That is, the orbit should fill a finite region of the space in this plane, if there are no other conserved quantities. But we are always taught that the bound motion is an ellipse in the xy-plane, which is an one-dimensional curve. So, there must exist yet another conserved quantity for the inverse square law force which keeps the planet in one dimension rather than two. And indeed there is, which provides a really nice way of solving the Kepler problem.

To discover this last constant, consider the time derivative of the quantity $\mathbf{p} \times \mathbf{J}$ in any central force $f(r)\,\hat{\mathbf{r}}$. With a little bit of algebra, you can show that

$$\frac{\mathrm{d}}{\mathrm{d}t}(\mathbf{p} \times \mathbf{J}) = -\,mf(r)\,r^2\,\frac{\mathrm{d}\hat{\mathbf{r}}}{\mathrm{d}t} \tag{8}$$

The miracle of inverse square force is again in sight: When $f(r)r^2$ = constant $= -GMm$, we find that the vector

$$\mathbf{A} \equiv \mathbf{p} \times \mathbf{J} - \frac{GMm^2}{r}\mathbf{r} \tag{9}$$

is conserved. But we needed only one more constant of motion, now we have got three which will prevent the particle from moving at all! No, it is not an overkill; one can easily show that A satisfies the following relations:

$$A^2 = 2\,mJ^2E + (GMm)^2; \;\; \mathbf{A} \cdot \mathbf{J} = 0\,. \tag{10}$$

The first one tells you that the magnitude of $\mathbf{A}$ is fixed in terms of other constants of motion and so is not independent; and the second shows that $\mathbf{A}$ lies in the orbital plane. These two constraints reduce the number of independent constants in $\mathbf{A}$ from 3 to 1, exactly what we needed. It is this extra constant that keeps the planet on a sensible orbit (i.e. a closed curve!). To find that orbit, we only have to take the dot product of (9) with the radius vector $\mathbf{r}$ and use the identity $\mathbf{r} \cdot (\mathbf{p} \times \mathbf{J}) = \mathbf{J} \cdot (\mathbf{r} \times \mathbf{p}) = J^2$. This gives

Stepping into Kepler's shoes

You must have read that Kepler analysed the astronomical data of Tycho Brahe and arrived at his laws of planetary motion. Ever wondered how exactly he went about it? Remember that the observations are made from the Earth which itself moves with an unknown trajectory! Suppose you were given the angular positions of all the major astronomical objects over a long period of time, obtained from some fixed location on Earth. This is roughly what Kepler had. How will you go about devising an algorithm that will let you find the trajectories of the planets ? Think about it!

$$\mathbf{A} \cdot \mathbf{r} = Ar \cos \theta = J^2 - GMm^2 r \tag{11}$$

or, in more familiar form,

$$\frac{1}{r} = \frac{GMm^2}{J^2} \left(1 + \frac{A}{GMm^2} \cos \theta \right). \tag{12}$$

As a bonus we see that **A** is in the direction of the major axis of the ellipse. One can also verify that the offset of the centre in the hodograph, $(GM/h)\,e$, is equal to (A/h). Thus **A** also has a geometrical interpretation in the velocity space. It all goes to show how special the inverse square law force is! If we add a component $1/r^3$ to the force, (which can arise if the central body is not a sphere) J and E are still conserved but not **A**. If the inverse cube perturbation is small, it will make the direction of **A** slowly change in space and we get a 'precessing' ellipse.

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Suggested Reading

- **Sommerfeld A. Lectures on Theoretical Physics. *Mechanics*. Academic Press. Vol.I, p.40**
- **Rana N C and Joag P S. *Classical Mechanics*. Tata McGraw Hill. p.140**

Poisson Mathematics

That Poisson liked teaching can be seen from his own words: "Life is made beautiful by two things — studing mathematics and teaching it". (From: *The Mathematical Intelligencer*, Vol.17, No.1, 1995)

The Secretary Problem

Optimal Stopping

Arnab Chakraborty

In many spheres of activity, decisions must often be made under uncertain conditions. One such problem relates to selecting a candidate from a known number when: (a) candidates arrive in a sequence; (b) the selection process has to decide on a candidate then and there; (c) the process terminates if a candidate is selected; (d) the process continues if the candidate is not selected. The question is: What is the strategy that maximises the probability of selecting the best candidate? How does one use the 'scores' of each of the candidates seen so far to decide if the present candidate must be selected or if the process be continued, in the quest for the best candidate? This is the problem of *optimal stopping*, an example of which is discussed here.

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Let us suppose that the managing director (MD) of a firm wants to employ a private secretary and has to select one out of ten candidates on the basis of an interview. The candidates, however, cannot all come on the same day; they come on different days and have to be either offered the position right away or be rejected. Once a candidate has been offered the job the others are asked not to bother to come for an interview. After each interview the MD gives the candidate a score. Naturally, she wants to appoint the person with the highest score (the best person). The MD thus has a problem. How on earth can she know before hand whether some future candidate will not be better than the ones she has interviewed already? Thus she has to work under the scenario where the order in which the ten candidates come can be any one of the 10! possible permutations of 10 persons, say with equal probability; that is, the candidates arrive in a *random order*, to use a statistical term. It is obvious that under these circumstances, there is no strategy which ensures that the MD will **always** get

Consider now the probability that a particular selection strategy gets the right candidate. If we can get these probabilities for all the possible strategies (a large set, no doubt!) then possibly we may get hold of the strategy with the highest probability and declare that as the 'best' strategy.

the right person. Thus, one way of approaching this problem is to try and work out a strategy by which the *probability* of getting the best candidate is the highest for all strategies. By strategy here, we mean a procedure which tells the MD what action to take – select or reject – at the end of each interview using the scores of all candidates interviewed thus far. For instance, a strategy may say: leave the first three candidates and select the candidate after that whose score exceeds the scores of each of his/her predecessors and if this does not happen at all, select the last candidate. We shall examine strategies like these below.

This may not be a completely satisfactory formulation of the problem. After all, although the MD wants the best candidate, she may be quite happy with a candidate whose score is fairly close to that of the best. So, another way of formulating the problem, taking into account the chance elements involved, may be to ask for a strategy which will minimise the expected value (see R L Karandikar 1996, On randomness and probability, *Resonance*, Vol. 1, No. 2, pp. 55–68, for a definition of expected value) of the difference between the scores of the best and the selected one. However, in our formulation, we have concentrated on getting the best.

It appears a bit unrealistic that the candidates arrive at different times and have to be told the results right away. However, there are situations in which this may actually happen. For instance, in the traditional Indian method of finding a spouse, alliances are generally considered one by one, each case evaluated with respect to various considerations (and say, a score is given) and the alliance accepted or rejected[1]. Realistically, the number of 'alliances' that can be considered is not known.

Consider now the probability that a particular selection strategy gets the right candidate. If we can get these probabilities for all the possible strategies (a large set, no doubt!) then possibly we may get hold of the strategy with the highest probability and declare that as the 'best' strategy. In this way, probability helps us to

[1] For obvious reasons this problem is also called the *dowry problem* or the *marriage problem* in the literature.

compare strategies whose outcomes depend on chance. Statisticians call such problems of choosing strategies as *decision problems*.

In a decision problem, we take both the losses and the probabilities of incurring them into account, and act accordingly.

Such decision problems often occur in our daily lives. In the rainy season, we all have to make a decision as to whether to carry an umbrella or not when we venture out. Here you have to choose between the actions:

(a) Take umbrella.
(b) Do not take it.

If you follow (a) then either (1) it rains and you use the umbrella, or (2) it does not rain and you have carried the umbrella in vain.

If you follow (b) then either (1) it rains and you get drenched, or (2) it does not rain and you did not have to carry the umbrella as a burden.

You can never be sure about the rain. (Some people say that it will surely not rain if and only if the weather bureau predicts rain; if it is so, then of course there is no problem!) So your decision has to be based on assessments of chances, heuristically or scientifically. Also, you compare the penalties to be paid for wrong decisions. Most of us consider getting drenched a more serious loss or penalty than the burden of an umbrella. That is why even a few clouds in the sky finds us carrying umbrellas. So, in a decision problem, we take both the losses and the probabilities of incurring them into account, and act accordingly.

But the situation that the MD faces is slightly different. To understand this let us make a game out of the MD's problem. It will take two to play it. First you write 10 distinct numbers (unknown to your opponent) on 10 pieces of identical-looking paper. Fold the pieces and mix them well. Your opponent plays the role of the MD. She randomly draws one paper, unfolds it and sees the number on it. If she signals 'acceptance' the game

terminates. Otherwise she throws away that paper and selects another paper randomly from the rest, and the game continues. If she comes to the last paper, she has to accept it and, of course, the game terminates there. When the game terminates, the MD wins the game if what she accepts is the maximum number. Otherwise, she loses the game. You can see that this game imitates the secretary selection procedure. Repeat this game a large number of times (with different sets of numbers, of course) and find out how many times the opponent (MD) wins.

The object here is to find a strategy with the highest probability of choosing the best person.

With this game in hand we are ready to investigate the problem of the MD more deeply. Firstly, notice the difference between the umbrella problem and the MD's problem. In the umbrella problem, the decision was to be made just once. In the MD's problem, a decision is to be made after each interview in a sequential manner. In the umbrella problem, if some expert tells us that the probability of rain that day is 0.7 and if we quantify the loss or penalty for getting drenched and for carrying the umbrella, the problem is solved immediately. Let the loss in getting drenched be Rs 10 (the amount required to wash your clothes and for the medicine to treat the consequent cold) and the loss in carrying the umbrella is Rs 2 (let us say that you have to drink a cup of tea to relax your arm muscles), then the computation goes as follows:

Expected loss in *not* carrying umbrella: Rs $10 \times 0.7 = 7.0$
Expected loss in carrying umbrella: Rs $2 \times 0.3 = 0.6$

Evidently, it is better to carry an umbrella. This computation is explained as follows: If you do not carry an umbrella, there is loss only if it rains; the expected loss is the amount of loss (Rs 10) multiplied by the probability of rain (0.7). Similarly, if you carry an umbrella there is loss only if it does not rain and the expected loss is the amount of loss (Rs 2) multiplied by the probability of no rain (0.3). Similarly, if the probability of rain is 0.2, then the expected losses are 2 and 1.6 respectively and it is still better to carry the umbrella. If the probability of rain is 0.1, then these

numbers are respectively 1 and 1.8 and it is better not to carry the umbrella.

But in the MD's problem, there is only one correct decision and thus there is no question of loss or expected loss. The object here is to find a strategy with the highest probability of choosing the best person. To outline the solution is not difficult and we do it now. We do it in terms of the game.

First, it is easy to see that what matters is the order or rank of the numbers and not the actual numbers themselves. Suppose you have drawn (and rejected) 5 papers bearing the numbers 1, –2, 59, 2.3, 7.999. The 6th paper that you draw shows the number 10. Will you accept it? Surely not, since it has already been exceeded by 59 and so this cannot be the maximum number. Hence:

First, it is easy to see that what matters is the order or rank of the numbers and not the actual numbers themselves.

RULE 1: Never accept a paper bearing a number less than any on the previously drawn papers.

So we confine our attention only to those papers that show numbers higher than their predecessors. These papers, including the first one drawn, will henceforth be called 'hopefuls'. (In the literature these papers are called 'candidates', but to avoid confusion with the candidates for the secretary's post, we are using a different terminology.)

Consider once more the first draw. There is only one paper that you have seen and all the other nine are lying folded on the table. The probability that the maximum number is among those nine is obviously quite high. Suppose you reject that paper and the paper drawn next is a hopeful (otherwise reject that also by Rule 1). Now the probability that the maximum is among the remaining papers is less than that at the first step. Thus the probability that the maximum is yet to come gradually decreases as you go along and the probability of winning increases as you keep going. This, at first, seems to mean that we should go on and accept the tenth candidate. This argument, unfortunately, is incorrect, since the

tenth paper may not be a hopeful; if it is, then of course we are sure to win.

Thus the best strategy is now clear. At each draw, apply Rule 1 to reject any non-hopefuls. If the draw is a hopeful, then compare

(a) the probability of winning by accepting it, and
(b) the probability of winning by rejecting it.

If (a) is higher, accept the draw; otherwise, reject the draw and proceed to the next draw. At the last draw, accept.

Thus the best strategy is now clear. At each draw, apply Rule 1 to reject any non-hopefuls.

So all that remains to be done is to compute these probabilities. As pointed out earlier, these only depend on n, the number of candidates and not on the numbers on the papers, so long as they are distinct. We know that the probability (a) increases with draws and (b) decreases with draws. Thus initially (b) is high and hence you should go on rejecting the first few initial draws. Then after a certain stage, say, after the x^{th} draw (b) is less than (a). Therefore from the $(x+1)^{th}$ onwards you should accept at the very first draw which is a hopeful. This is the best strategy. Computation of these probabilities is somewhat technical and is explained in the sequel; however, we give here a table of the probabilities for $n=10$. From this it is evident that the right choice of x is 3 (when n is 10); that is, leave the first three draws and from the fourth draw accept the first one for which the number is greater than all the previously seen numbers. Of course, if you are at the tenth draw, just accept it. The probability of winning at each draw is shown in the table. In terms of the MD's problem, the MD should reject the first three candidates and from the fourth accept the one whose score is higher than all the earlier ones; if however it is the tenth candidate, accept. Of course, as mentioned earlier, once a candidate is selected no more candidates will be interviewed. It goes without saying that if n is different from 10, these probabilities and hence the value

Table 1. Probabilities of Winning by Accepting the next 'Hopeful' after the $(x+1)^{th}$ Draw Onwards (n=10)

x	Probability	x	Probability
0	0.100	5	0.373
1	0.283	6	0.327
2	0.366	7	0.265
3	0.399	8	0.189
4	0.398	9	0.100

of x will change. As you can see, the value of x will monotonically increase with the value of n.

Let us now explain how a table like this is obtained. This requires a bit of analysis and some concepts like *conditional probabilities*. Let us call the strategy which skips the initial s candidates $(0 \leq s \leq n-1)$ and selects the first hopeful after that as STRAT(s). We want to compute

$$P(\text{Win by STRAT}(s)).$$

Now, STRAT(s) can possibly win only when the maximum occurs at a draw after the s^{th} draw. Suppose the maximum occurs at the k^{th} draw $(s+1 \leq k \leq n)$. Then

$$P(\text{Win by STRAT}(s))$$

$$= \sum_{k=s+1}^{n} P(\text{Win by STRAT}(s) \text{ and maximum is at the } k^{\text{th}} \text{ draw})$$

$$= \sum_{k=s+1}^{n} P(\text{Win by STRAT}(s) \mid \text{maximum is at the } k^{\text{th}} \text{ draw})$$

$$\times P(\text{maximum is at the } k^{\text{th}} \text{ draw}). \qquad (1)$$

But the order being random, the maximum may occur at any of the n draws $1, 2, \ldots, n$, with equal probability $1/n$. Hence $P(\text{maximum is at the } k^{\text{th}} \text{ draw}) = 1/n$.

Now we focus our attention on the term

P(Win by STRAT(s) | maximum is at the k^{th} draw), $(s+1 \leq k \leq n)$.

Since the draw showing up the maximum is always a hopeful, all that needs to be ensured for a win is that it is the first hopeful after the s^{th} draw. This happens only if the maximum of the initial $(k-1)$ draws lies within the first s draws. But, due to randomness of the order, this maximum may be at any of the initial $(k-1)$ draws with equal probability $1/(k-1)$. Hence the chance of its being among the first s draws is $s/(k-1)$. Thus

$$P(\text{Win by STRAT}(s) \mid \text{maximum is at } k^{\text{th}} \text{ draw})$$

$$= \frac{s}{k-1}, \quad (s+1 \leq k \leq n).$$

Since the draw showing up the maximum is always a hopeful, all that needs to be ensured for a win is that it is the first hopeful after the s^{th} draw.

So, we have from (1)

$$P(\text{Win by STRAT}(s)) = \frac{s}{n} \sum_{k=s+1}^{n} \frac{1}{k-1}$$

$$\frac{s}{n}\left[\frac{1}{s} + \frac{1}{s+1} + \cdots + \frac{1}{n-1}\right] = \pi(s, n), \text{ say.} \tag{2}$$

The interested reader may check that the probabilities tabulated above are indeed the values $\pi(s, 10)$ as s varies from 0 to 9.

Let $s*$ (which may depend on n) maximise $\pi(s, n)$ for a fixed n. That is, let

$$\pi(s*, n) \geq \pi(s, n) \text{ for all } s.$$

It is easy to check that this is the same as

$$\frac{1}{s*} + \frac{1}{s*+1} + \cdots + \frac{1}{n-1} \geq 1 \geq \frac{1}{s*+1} + \cdots + \frac{1}{n-1}. \tag{3}$$

From this we can see that $s* \to \infty$ as $n \to \infty$. Now recall from analysis the following result:

Result: $\sum_{i=1}^{n} \frac{1}{i} \approx \ln(n) + C$, where C is the Euler's constant.

Using this result we have from (3)

$$\ln\left(\frac{n-1}{s*}\right) \approx 1 \text{ for large } n \text{ (that is, for large } s* \text{ also),}$$

$$\text{that is } \ln(n/s*) \approx 1 \text{ for large } n$$

$$\Rightarrow s* \approx n/e \text{ for large } n. \qquad (4)$$

This means that if n is large, you need not do the tedious maximisation of $\pi(s, n)$. Rather, just divide n by e and the integer nearest to the answer gives you the value of $s*$. What is the probability of winning now? To find out, apply the above result to (2) to get

$$\pi(s, n) \approx \frac{s}{n} \ln\left(\frac{n-1}{s-1}\right) \text{ for large } n \text{ and } s$$

$$\approx \frac{s}{n} \ln\left(\frac{n}{s}\right) \text{ for large } n \text{ and } s.$$

Therefore

$$\pi(s*, n) \approx \frac{s*}{n} \ln\left(\frac{n}{s*}\right)$$

$$\approx \frac{1}{e} \text{ for large } n \text{, by (4).}$$

Here is an example: Suppose you are the MD and 1000 candidates appear at the interviews. Then, this is what you should do: Compute $(1000/e) = 367.9 \approx 368$. Having done that, you only score the first 368 candidates and not offer them the job. Then on,

This means that if n is large, you need not do the tedious maximisation of $\pi(s, n)$. Rather, just divide n by e and the integer nearest to the answer gives you the value of $s*$.

you select the first candidate whose score exceeds all the previous ones. By this process, you have a 36.79% chance of securing the best candidate. Do not feel disheartened by such a low probability. Remember that this is the maximum possible probability.

As pointed out earlier, if you formulate the problem differently, the solution will also be different. In any case, problems of this sort are often successfully tackled by a probabilistic or statistical formulation. For this, as you have seen here, probability calculations are required. Some of these probability calculations pose challenging and interesting mathematical problems and it is no wonder then that the theory of probability is such a fascinating subject!

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Suggested Reading

- J H Fox, L G Marnie. Martin Gardner's column *Mathematical Games*. *Sci. Am.* 202:150-153, 1960.
- J P Gilbert, F Mosteller. Recognizing the maximum of a sequence. *J. Am. Stat. Assoc.* 61:35-79, 1966.
- J D Petruccelli. Secretary problem. *Encyclopedia of Statistical Sciences*. (Eds) S Kotz, N L Johnson and C B Read. Wiley New York. 8:326-329, 1988.

In *Scientific American,* 1961... Cosmonaut Yuri A Gagarin has become the first person to cross "the border between the earth and interplanetary space" in his spaceship *Vostok*.
A report on the design and construction of satellites engineered to transmit telephone and television signals predicts that the first of these systems will be operating within five years. Progress is faster than expected, and less than a year later *Scientific American* tells of the successful launch of Bell Telephone Laboratories's *Telstar*. (From *Scientific American*, September 1995)

Hydrodynamic Lubrication

Experiment with 'Floating' Drops

Jaywant H Arakeri and K R Sreenivas

s article gives the principle of hydrodynamic ·ication and also presents the new phenomenon of tating drops over liquid film flow, which is explained ıg hydrodynamic lubrication theory.

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Sreenivas K R is a research student in the Department of Mechanical Engineering and works in the area of convective heat transfer.

·oduction

tion plays a large and essential role in everyday life although ısually never think about it. For example, friction provides support when we walk; without it we would not be able to ·e forward and indeed it would be impossible to stand up ıout additional support. When we grip an object and stop it ı falling we again use friction.

ıany engineering systems, however, when two surfaces slide ıst one another friction is a nuisance. In this case friction has undesirable effects: (1) it increases wear and (2) work that is useful, needs to be done to overcome it. Thus, reducing :ion will not only increase the life of a component but also ease the efficiency of the system.

:tion between surfaces may be reduced by lowering the ficient of friction; or it may be reduced by introducing a new stance – a lubricant – between the surfaces. The lubricant can olid (e.g. graphite) or fluid (oil, water, air). The lubricant ıld also be able to support a load, if any, acting normal to the ace.

Friction between surfaces may be reduced by lowering the coefficient of friction or by using a lubricant.

ırodynamic lubrication is one method used extensively to port load and reduce friction. In this article we describe a

Friction plays a large and essential role in everyday life although we usually never think about it.

simple but fascinating experiment, which may easily bedone in a school or college laboratory (or even at home), that demonstrates hydrodynamic lubrication.

Principle

To understand the principle of hydrodynamic lubrication consider a block sliding on a horizontal table (*Figure 1a*). The force required to move it with constant velocity is equal to the frictional force = μW; μ is the coefficient of sliding friction and W is the weight of the block. For many common surfaces μ is about 0.3. Thus we would require 0.3 kg force to slide a block weighing 1 kg.

If we now put a liquid film of thickness h between the block and the table surface (*Figure 1b*) the force required to move the block with constant velocity u is $P = \eta\, u A / h$; η is the coefficient of viscosity of the liquid and A is the bottom surface area of the block. Note that now the friction force depends on the velocity of the block. As an example let the block slide over a 0.1 mm water film with a velocity of 20 cm/s (about walking speed). Then $P =$ 0.03 kgf, a tenth of the earlier friction force. But this reduction in friction is useless as the liquid film as shown in *Figure 1b* cannot support the weight of the block. The liquid will flow out of the sides under the weight.

What we need is not only that the friction be reduced but also that the weight be supported. Both are achieved if the block tilts slightly forward as it moves (*Figure 1c*).

In many engineering systems, when two surfaces slide against one another friction is a nuisance.

It may seem counter-intuitive that the block should tilt forward instead of back to support the load. The support of the weight, i.e., the *bearing action*, is explained as follows. The block, as it moves forward, drags the liquid into the gap. This liquid has to move into a gap which is narrowing and the pressure that builds up in the gap supports the load. Note the two important ingredients for bearing action: one is motion which drags the

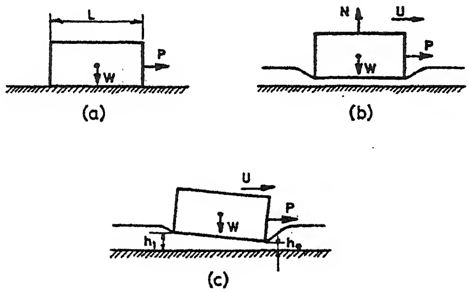


***Figure 1** A rectangular block of length L, surface area A and weight W sliding to the right with velocity U under different conditions. Force P is required to slide the block. (a) Block sliding on a solid surface, P = friction force = μW. A normal reaction exerted by the table surface supports the weight. (b) Block sliding with the bottom surface parallel to the table surface on a liquid film. P = $\eta(UA/h)$ where η is the viscosity of the liquid. To support the weight, an external force N = W is required. (c) Block sliding on the liquid film but tilted forward (i.e., $h_0 < h_1$). P is same as in Figure 1b but now a 'bearing' pressure develops in the film which supports the weight. Bearing pressure arises as the liquid is dragged to the right into a narrowing gap.*

liquid and the other is dragging of the liquid into a narrowing gap or a constriction. If either ingredient is absent the load cannot be supported.

Let us look at the various parameters that affect the load carrying capacity

$$W \simeq C\frac{\eta UAL}{h_0^2}$$

($C = 0.07$ for $L/B = 1$ and $h_1/h_0 = 2$. Here L is the length of the block and B is the width. The form of the equation remains unchanged with changes in the values of the two ratios; only the constant C changes). The frictional force,

$$F \simeq \eta\frac{UA}{h_0}$$

Hydrodynamic lubrication is one method used extensively to support load and reduce friction.

When we slip wearing rubber-soled slippers on a wet bathroom floor, it is a manifestation of hydrodynamic lubrication!

is about the same as when the gap is parallel. Interestingly the coefficient of friction $= F/W = h_0 / (CL)$ is independent of the value of viscosity.

Note for a given area (A) and length (L) the load that can be supported increases linearly with speed and viscosity and inversely as the square of the gap. Therefore generally, hydrodynamic lubrication is associated with surfaces having relative motion, small gaps and high viscosity oils. Under special circumstances however, like light loads or high speeds, air bearings have been used.

[1] *Reynolds number* is a measure of the ratio of inertia to viscous forces and is, perhaps, the most important dimensionless number in the study of *fluid mechanics.*

There are two conditions under which hydrodynamic lubrication and the associated bearing action occur. One is that the Reynolds number[1] be small, i.e., when $\rho U h_0 / \eta \leq 1$. Here, ρ is the density of the fluid in the gap. A low Reynolds number implies that viscous forces are important and are in fact responsible for the dragging in of the fluid and the resulting pressure build up. The second condition is that the angle of the narrowing passage (angle of tilt in *Figure 1c*) be small.

Hydrodynamic lubrication finds a number of engineering applications, the most common being the *journal bearing* (see *Box*). When we slip wearing rubber-soled slippers on a wet bathroom floor, it is a manifestation of hydrodynamic lubrication!

'Floating' drops

Now we describe the fascinating but simple experiment which illustrates hydrodynamic (really aerodynamic) lubrication. Take a glass tube of internal diameter 1/4" ($\approx$ 6 mm) connected to one end of a flexible (say rubber) pipe. The other end of the flexible pipe is dipped in a container (bucket) of water. Let the water flow out of the glass tube by siphon action. Use a valve to adjust the flow rate.

Journal Bearing

The most common example of hydrodynamic bearing is the journal bearing (*Figure 2*). It is a circular shaft (journal) rotating inside a circular bush with a thin film of oil separating the two. The gap between the shaft and the bush is generally about 0.001 to 0.002 times the shaft diameter. Usually a load *W* (eg. weight of the impeller in a pump) has to be supported. When the shaft is rotating, position of the shaft with respect to the bush is shown in *Figure 2b*. Rotation of the shaft drags in the oil into a narrowing gap (marked A in the *Figure*). According to our discussion earlier, bearing pressure develops and this in turn supports the load. The oil film ensures low wear and low friction. In practice, the design must ensure a minimum film thickness to prevent breakage of the film and the subsequent contact between the shaft and the bush surfaces. When the load is high or the shaft speed is low this minimum film thickness cannot be maintained. In these cases roller element bearings (eg. ball bearings) or hydrostatic bearings are used. Interestingly even in ball bearings, we have hydrodynamic lubrication at the ball surface.

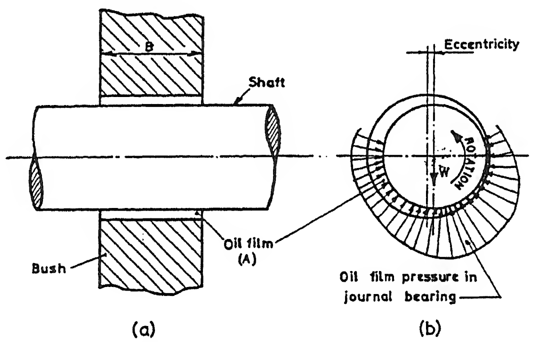


Figure 2 Journal bearing (a) front view indicating shaft, bush and the oil-film. (b) cross-section in the side view indicating the pressure developed in the oil-film and the relative positions of shaft and bush when the shaft is rotating.

Let the jet of water impinge on a horizontal surface (eg. glass plate) kept about 8 cm below the end of the glass tube. We get a thin film of water which flows radially outward. At some distance we observe that the film height abruptly increases. This is known as a *hydraulic jump*. (Hydraulic jumps are commonly observed in flowing streams, rivers, etc. Hydraulic jumps are analogous to

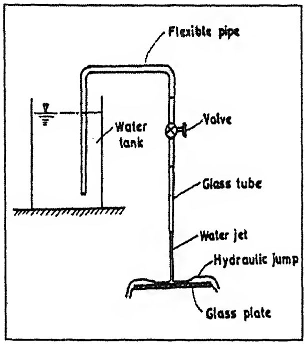


Figure 3 Schematic diagram of the set-up.

Figure 4 Photograph showing release of a liquid drop above the film and just ahead of the hydraulic jump. The syringe is slowly withdrawn once the desired drop size is reached.

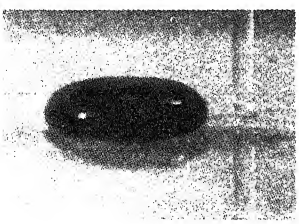


Figure 5 Photograph indicating the water jet and a levitating water drop. Dye in the drop gives the dark colour.

shock waves in air formed, for example, when an airplane flies at supersonic speeds.) The radius at which the jump occurs increases with flow rate. For the present experiment keep the flow rate ($\approx$ 7 cc/s) such that the radius of the jump is about 2 cm. It must be ensured that the water jet is steady. The water jet coming out of a tap will not do as the flow is usually 'disturbed' and unsteady. *Figure 3* shows a schematic of the set-up.

Once the jet flow is set up, take water in a syringe. Place the tip of the syringe needle close to the surface of the film and just ahead of the hydraulic jump. Slowly release a small drop of water by pushing the piston (*Figure 4*). Take the needle out of the drop. You will see that the drop will not mix with the flowing water film but 'float' (*Figure 5*). There cannot be contact between the drop and the film because then the two would just mix. Actually there is a very thin ($\approx$10 μm) air layer below the drop; the drop is not really floating but levitating on this air layer. Some skill needs to be developed to conduct the described experiment.

It can be shown that the drop is supported by bearing action. The flowing film drags in air into a narrowing gap below the drop (*Figure 6*). The resulting pressure build-up supports the drop. The hydraulic jump is essential to keep the drop stationary; it prevents the drop from flowing with the stream.

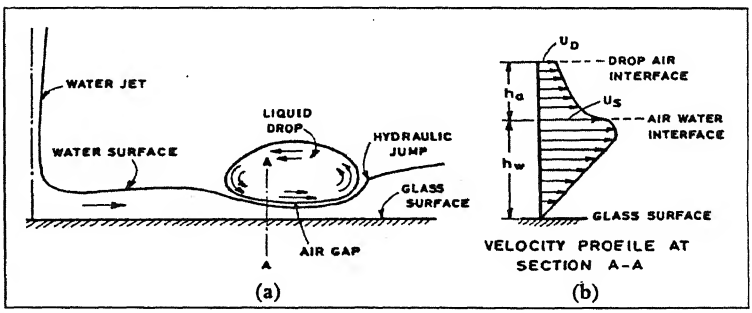


Figure 6 (a) Schematic showing the water jet, flowing water film, air gap and induced motion in drop. (b) Velocity profile in the air layer and the water film. Induced velocity in the drop, U_D, is small for viscous drops. Film thickness $h_w \approx$ 0.1 mm and air-gap thickness, h_a is estimated to be $\approx$ 10 μm.

The drop-liquid need not be of water. Drops of oil, soap water, glycerol, etc. levitate; but drops of liquid like alcohol, having high evaporation rates and which are miscible in water do not levitate.

Depending on the drop size and drop liquid properties (viscosity and surface tension) a fascinating variety of shapes are obtained (*Figure 7*).

Depending on the drop size and drop liquid properties a fascinating variety of shapes are obtained.

We can explain the different shapes by considering a balance of forces. First consider the balance of forces on one-half of the drop:

- We find that motion is induced in the drop: it 'spins' about the horizontal axis as shown in *Figure 6*. We call the force associated with this motion *inertia force*. Higher the viscosity

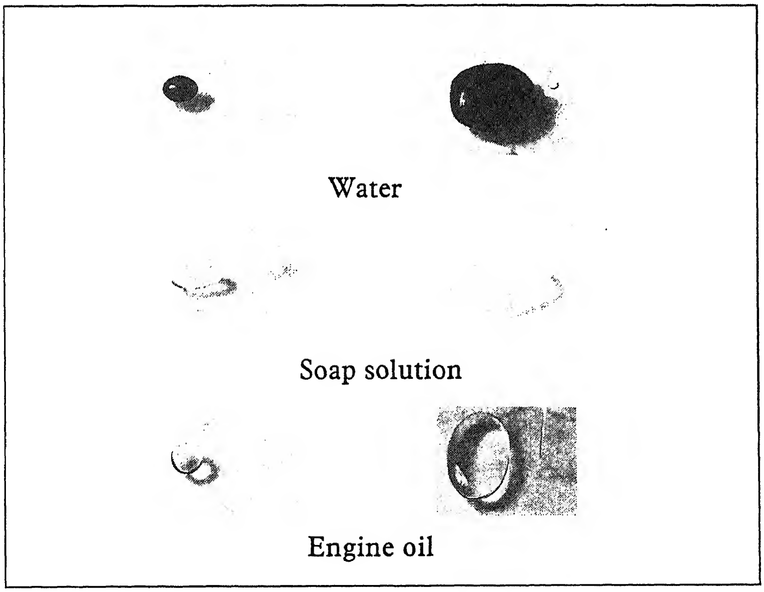
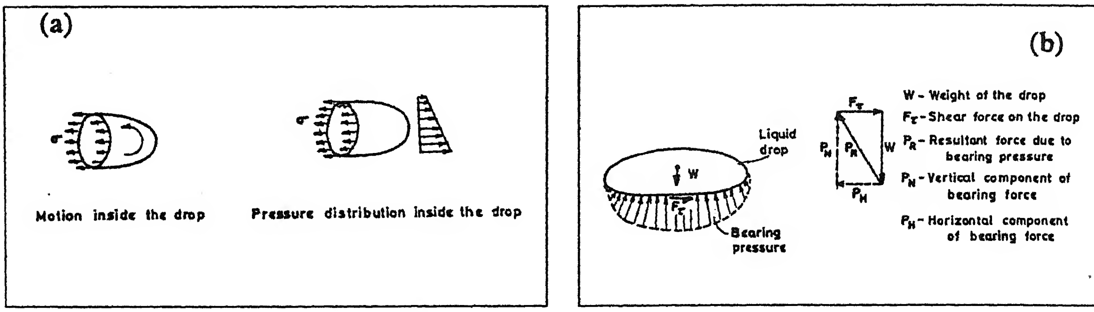


Figure 7 Photograph showing the effects of drop size and drop liquid properties on the drop shape. Volumes of the drops in the left hand column are about 0.1 ml and of those in the right hand column are about 1 ml. The 1 ml drops are 'flatter' compared to the 0.1 ml drops. Very little motion is induced within the engine oil drops because engine oil is very viscous. Shortening of the 1 ml engine oil drop is due to external forces. Soap-solution has lower surface tension than water. Thus soap-solution drops are elongated in comparison with water drops.



Figures 8a and 8b . (8a) Internal force balance. Surface tension force (σ) balances forces due to inertia and hydrostatic pressure. (8b) External force balance, weight (W) of the drop is balanced by the vertical component (P_N) of the resultant force (P_R) developed due to bearing action. The horizontal component of bearing force P_H balances the shear force (F_τ) exerted by the flowing air.

of the drop liquid, lower is the induced motion and thus lower is the inertia force.

- Due to gravity the pressure inside the drop increases linearly. We call the force due to this pressure *gravity force*.
- Force due to surface tension.

We have two external forces for horizontal equilibrium of the full drop (*Figure 8b*): shear force exerted by the air and horizontal component of the bearing force.

The inertia force arises due to the fact that the fluid has to turn around 180° and is balanced by the surface tension force. A higher inertia force elongates the drop in the flow direction. The gravity force is again balanced by surface tension and tends to flatten the drop: larger drops are flatter. For small drops, surface tension dominates and drops are nearly spherical. The external forces balance each other and tend to shorten the drop in the flow direction.

An interesting and relevant question is whether solid (e.g. plastic) spheres will levitate in the same manner as liquid drops. The answer is no. A deformable surface is necessary so that there is sufficient area over which the bearing pressure can act.

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What's New in Computers?

Will a Computer Become the World Chess Champion?

K S R Anjaneyulu

There has recently been significant interest in the area of computer chess. In February this year, Garry Kasparov, the world chess champion played a six match chess tournament with *Deep Blue*, the current computer chess champion. Garry Kasparov won the tournament, but lost one of the matches. This article describes the area of computer chess and the *Deep Blue* system.

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Why Computer Chess?

Computer chess has been an active area of interest since the beginning of the computer age. One may ask why chess has evoked so much interest.This is partly because of the complexity of the game. People who initially worked in Artificial Intelligence (AI) thought that chess was a good place to experiment with ideas in AI.

Claude Shannon, the founder of information theory, stated in 1950 that "the investigation of the chess-playing problem is intended to develop techniques that can be used for more practical applications." Shannon further argued that chess represents the ideal hurdle for computer analysis. "The problem is sharply defined, both in the allowed operations (the moves of chess) and in the ultimate goal (checkmate). It is neither so simple as to be trivial nor too difficult for satisfactory solution."

Definitions of AI

Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better. *Elaine Rich, 1983.*

Artificial Intelligence is that branch of computer science dealing with symbolic, non-algorithmic methods of problem solving. *Bruce Buchanan and Edward Shortliffe, 1984.*

Since the board is small, the number of rules is few and chance does not play a role, so one would think that it should not be difficult to design a computer chess machine. The problem however is the very large number of possibilities which need to be explored. The number of moves is so large that no machine will

be able to explore all of them.

History of Computer Chess

In 1957, Herbert Simon, one of the pioneers in the field of AI, predicted that we would be able to produce a computer chess machine which could beat any human being in 10 years. It turned out that this prediction was way off the mark, and even 40 years hence we have not achieved that. However, this is not to rob the AI community of credit. Computer chess performance has improved by about 50 points each year.

Claude Shannon, the founder of information theory, stated that "the investigation of the chess-playing problem is intended to develop techniques that can be used for more practical applications."

The international chess association started a world-wide chess competition in 1974. In this competition computer chess machines clash with each other to determine 'who' is the best. In addition there are the Fredkin prizes which are awarded to chess machines for outstanding performance. The *Belle* program written by Ken Thompson (one of the developers of the UNIX operating system) won the Fredkin's prize of $5000 in 1983 for being the first machine to achieve a master's ratings. *Deep Thought* in 1989 won the $10,000 Fredkin's prize for being the first computer to attain a grandmaster's rating. The $100,000 prize for the first computer that becomes the world champion is still unclaimed.

How do Computers Play Chess?

The general procedure used by computers to play chess is given below. This procedure will play a perfect game of chess.

1. Every time a move has to be made, select the best move on the assumption that your opponent will also do the same.
2. How does one select the best move? For this one needs to generate the possible moves and select a move (The moves can be generated using the rules of chess). We can then examine the moves to see if they lead to a winning or a losing situation.
3. We then select one of the moves which leads to a winning situation. However, our move depends on the move our opponent makes. For this we select the best move which our opponent can

make and assume that he will make that move. (We can do this, by putting ourselves in our opponent's place and repeating the procedure we are using now).
4. The program thus keeps calling itself, continuing to expand possible moves and countermoves in an ever expanding tree of possibilities. So the game can be viewed as a tree, in which the nodes of the tree correspond to possible moves which can be made by the two players.
5. When does this end? It ends when we reach the end of the game.

If the procedure is simple, one would have thought that we would have had a world champion chess program long ago. The problem is the number of possibilities which need to be explored at each stage. If one needed to explore all possibilities before making one's first move, the amount of time required is estimated to be 40 billion years. How does one arrive at this figure? If you assume that a game lasts about 30 moves, we need to consider 8^{30} possible move sequences to fully expand the tree. If you assume that we can search 1 billion move sequences each second, we need 10^{18} seconds or about 40 billion years.

Human beings, while playing chess use an extremely complicated strategy which includes intuition, experience, memory and pattern recognition.

How do computers overcome this problem? Since the whole tree cannot be searched, we place limits on the tree's depth and height. By reducing the number of moves we can do this in a reasonable amount of time. However, we then run into a problem. In our procedure, we had said that we will be selecting a move based on whether it leads to a winning situation or not. Since we are not able to search the whole tree, we can only guess whether something leads to a winning situation or not. This is done by using heuristics which give us some measure of the goodness of a move in the tree.

This is quite different from how humans play chess. The reason this approach was adopted was because attempts to develop computer systems which use a lot of human-like chess intelligence were not successful. Human beings typically consider a much smaller number of positions for each move. They use an extremely

Computer chess programs primarily use variations of look ahead search. The improvements over the years have largely been in being able to look farther and wider.

complicated strategy which includes intuition, experience, memory and pattern recognition. It has not been possible to decipher this strategy in a form in which a computer can use it.

The following table from Raymond Kurzweil's book (see Suggested Reading list) gives an estimate of the number of rules and board positions considered by computers and humans respectively. An interesting observation from this table is that computers make up for their relative lack of knowledge (represented by smaller number of rules) by being able to search much deeper in the tree (represented by the large number of board positions which are examined). Another confirmation of this fact is that the best computer chess systems invariably seem to be the most powerful. The advances in the area of computer hardware and parallel programming have allowed these machines to search many more moves than was possible earlier.

	Human chess master	**Computer chess master**
Number of rules or memorized situations	30,000–100,000	200–400
Number of board positions considered for each move	50–200	10^6–10^{11}

Software Techniques used in Computer Chess

Computer chess programs primarily use variations of look ahead search. The improvements over the years have largely been in being able to look farther and wider. This is basically a function of raw processing power as mentioned earlier, but there have also been advances in software technology.

In order to produce better chess machines, researchers use a number of interesting techniques. Some of these techniques have general applicability and are also used in other areas of AI. The

procedure described earlier is called the *Minimax algorithm* and is well documented in books on AI.

There are other techniques such as forward pruning, move reordering, etc. which are used in a number of chess machines. In forward pruning, at each node in the tree, a subset of the possible children is considered for further exploration. This subset is normally based on some heuristic which indicates the goodness of a node. Move reordering tries to reorder nodes in a tree so that more plausible moves are explored before less plausible moves. There are many more techniques like these.

The basic version of *Deep Thought's* chess engine contained 250 chips and two processors on a single circuit board and was capable of analysing 750,000 positions per second.

Deep Blue Computer Chess System

Deep Blue's predecessor was a system named *Deep Thought* which was developed at the Carnegie Mellon University, Pittsburgh in 1988. This was created by a group of researchers including Feng-Hsuing Hsu and Murray Campbell.

The basic version of *Deep Thought's* chess engine contained 250 chips and two processors on a single circuit board and was capable of analysing 750,000 positions per second (a more powerful version was reported to be searching 1.6 million positions), for an international performance rating of 2450, which placed it in the lower ranks of the world's grandmasters. Kasparov played *Deep Thought* in 1989 and won quite easily.

IBM's *Deep Blue* project began in 1989 to explore the use of parallel processing to solve complex problems. The *Deep Blue* team at IBM, Feng-Hsuing Hsu, Murray Campbell (both from the *Deep Thought* project), A Joseph Hoane, Jr. Gershon Brody, and Chung-Jen Tan, saw this complex problem as a classical research dilemma to develop a chess-playing computer to test the best chess players in the world.

Deep Blue was designed to overcome many of the system limitations of *Deep Thought*, specifically in the areas of calculation

Deep Blue played a six match tournament against Kasparov in February this year. It lost the tournament, but won one of the matches.

speed and processing power. The research team aimed to build a machine which was a 1000 times more powerful than *Deep Thought* and which could examine close to a billion moves a second.

The *Deep Blue* computer is a 32-node IBM Power Parallel SP2 high-performance computer. Each node has 8 dedicated VLSI chess processors. So there are a total of 256 processors working in tandem. The system has been developed in the C programming language. This high degree of parallelism allows *Deep Blue* to check 50 to 100 billion moves within 3 minutes.

In addition to this, *Deep Blue* has a very large opening game database which has been built from grandmaster games played over the last 100 years. It also has an end game database which is activated when there are only five chess pieces remaining on the board.

Deep Blue played a 6 match tournament against Kasparov in February this year. It lost the tournament, but won one of the matches. This is significant since this is the first time a computer has beaten the world champion in a match played under normal tournament rules.

Moves of Game which Kasparov lost against Deep Blue.
Deep Blue plays White, Kasparov plays Black

1. e4 c5	9. Be3 cxd4	17. Bg6 Bb6	25. b3 Kh8	33. Nd6 Re1
2. c3 d5	10. cxd4 Bb4	18. Bxf6 gxf6	26. Qxb6 Rg8	34. Kh2 Nxf2
3.exd5 Qxd5	11. a3 Ba5	19. Nc4 Rfd8	27. Qc5 d4	35. Nxf7 Kg7
4. d4 Nf6	12. Nc3 Qd6	20. Nxb6 axb6	28. Nd6 f4	36. Ng5 Kh6
5. Nf3 Bg4	13. Nb5 Qe7	21. Rfd1 f5	29. Nxb7 Ne5	37. Rxh7
6. Be2 e6	14. Ne5 Bxe2	22. Qe3 Qf6	30. Qd5 f3	
7. h3 Bh5	15. Qxe2 O-O	23. d5 Rxd5	31. g3 Nd3	
8. o-o Nc6	16. Rac1 Rac8	24. Rxd5 exd5	32. Rc7 Re8	

When will a Computer be the World Chess Champion?

IBM claims that the design they have used for the *Deep Blue* system will allow them to construct chess computers with improved performance measured in orders of magnitude. Would Kasparov still be able to defeat the enhanced system? Maybe not.

Hans Berliner who has been involved in the development of chess machines at Carnegie Mellon University estimates that by 1998 the computer will be a world chess champion. Kurzweil estimates that it will be by the year 2000.

Kasparov believes that the very best players in the world should be able to exploit the special weaknesses presented by machines. Kasparov has long maintained that human creativity and imagination, especially his own, will always triumph over silicon. He says "Chess gives us a chance to compare brute force with our abilities. In serious, classical chess, computers do not have a chance in this century. I will personally take any challenge."

Some questions are difficult to answer. Will there be learning in the chess machines? Will they model their opponents in any manner to exploit their weaknesses and be aware of their strategies?

One thing is however definite. This is one arena where humans are pitted against AI in a dramatic manner. With the turn of the century inching closer, the battle gains increasing significance. If nothing else, an AI chess machine beating the world chess champion in a tournament will have a profound psychological impact.

Kasparov says "Chess gives us a chance to compare brute force with our abilities. In serious, classical chess, computers do not have a chance in this century. I will personally take any challenge."

Suggested Reading

- T A Marsland. Computer Chess Methods. Stuart C Shapiro (ed), *Encyclopedia of Artificial Intelligence*, Vol. 1. Wiley-Interscience,1987.
- Raymond Kurzweil. *The Age of Intelligent Machines*. The MIT Press, 1990.

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Molecule of the Month

Adamantane - A Plastic Piece of Diamond

J Chandrasekhar

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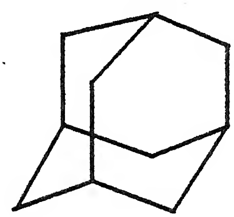
Several facets of adamantane chemistry are highlighted.

Chemists, like others, have long been fascinated by diamond. The challenging goal of making other substances with all the properties of diamond continues to be pursued, with some success. A more limited objective is to make small molecules which resemble diamond only at the structural level. Efforts to make and manipulate such 'diamondoid' systems have yielded interesting results.



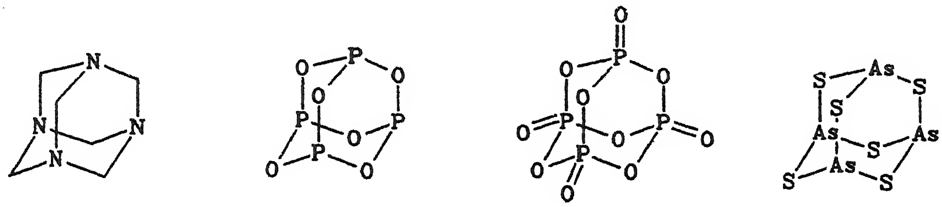
(1)

The 3-dimensional network structure of diamond, with each carbon having four tetrahedrally arranged neighbours, was figured out as early as in 1913. It is easy to recognise chair cyclohexanes, decalins, etc., (without the hydrogen atoms, of course) in the framework. If we look for something more complex, a cage containing 10 carbon atoms can be spotted. The corresponding hydrocarbon has the formula $C_{10}H_{16}$, and is called adamantane (1).

The adamantane molecule has tetrahedral (T_d) symmetry. The four cyclohexane units are all held rigidly in the preferred chair conformation. The molecule must therefore have negligible angle and torsional strain.

The challenging goal of making other substances with all the properties of diamond continues to be pursued, with some success.

Molecules with the adamantane skeleton are well known (*Figure 1*). The three-dimensional structure of a chemical called urotropine (hexamethylenetetramine) was formulated over 100 years ago. The trioxide and pentoxide of phosphorus are also known to exist as P_4O_6 and P_4O_{10} units with the adamantane structure. Another text book example with the adamantane skeleton is the arsenic sulfide As_4S_6.



Urotropine "P_2O_3" "P_2O_5" "As_2S_3"

Figure 1 Compounds having the adamantane structure.

Organic chemists set out to make the hydrocarbon version. Meerwein took the first steps. Others followed, but it was expected to be a long struggle. Suddenly, like a genie, adamantane literally popped out of a bottle. In Prague there was a large collection of samples of petroleum from different sources. In one of the samples taken from a village in Moravia (present day Czech Republic; or is it the Republic of Slovakia?) some crystals had formed. Landa, a well known chemist of his generation, noticed the crystals and carried out a chemical analysis. He found that the substance had a high melting point (270°C)[1] and had the molecular formula $C_{10}H_{16}$. He intuitively proposed that the substance ought to be adamantane. He was vindicated in 1941. After several synthetic steps, Prelog succeeded in making the desired cage compound. It turned out to be identical in all respects to the minor by-product from crude petroleum.

[1] It is not easy to determine the melting point of adamantane because it sublimes on heating.

The adamantane story remained fairly dormant for some time. After another 16 years, the molecule made another dramatic appearance. This time it was in the laboratory of Paul von Rague Schleyer at Princeton. He was trying to convert a C_{10} hydrocarbon from its *endo* form to the *exo* isomer, using aluminium chloride as the catalyst (*Figure 2*). After he distilled off the *exo* isomer, some crystals appeared from the nearly empty flask. Yes, it was the same high melting solid with the formula $C_{10}H_{16}$ (mass spectrometry had simplified the task of determining the formula). It was indeed adamantane, formed in one go.

Schleyer and many others took several years to show what had happened. Combining isotopic labelling experiments and

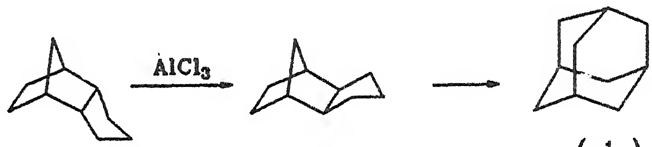


Figure 2 Lewis acid catalysed rearrangement of tetrahydrodicyclopentadiene. The first step was the expected reaction. The second was the 'lucky accident' recognised by 'the prepared mind'.

calculations, they were able to establish that the spectacular, deep-seated rearrangement occurs through a series of simple hydride and alkyl shifts involving several carbocation intermediates.[2]

[2] See the article on Wagner-Meerwein rearrangements by S Ranganathan, *Resonance*, Vol. 1, No. 1, 1996.

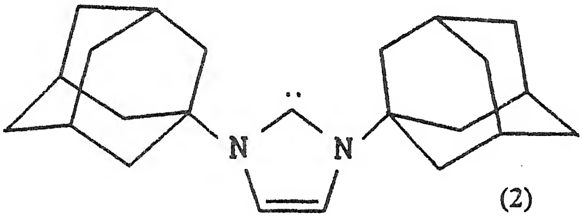
The chemical yield was initially only 15%. But improved methods have since been developed.[3] The rearrangement methodology, with appropriate precursors and catalysts, has been shown to be general enough to make other more complex cage compounds, including dodecahedrane, $C_{20}H_{20}$.

Adamantane is not a hard, lustrous substance like diamond. It is rather soft, white, resembling camphor. Disappointing and perhaps, but not surprising. After all, the molecules are held together only by van der Waals' forces. While the packing of spheroidal molecules would be efficient, there is likely to be a great deal of orientational disorder in the solid state. As a result, adamantane belongs to a class of materials called *plastic crystals*.

Adamantane did not end up as just another computer entry in the voluminous Chemical Abstracts Registry. Instead, the molecule opened up an important chapter in cage hydrocarbon chemistry. The availability of usable quantitites enabled chemists to transform adamantane into a variety of derivatives. These, in turn, have been used as probes to understand many aspects of structure, bonding and reactivity. I shall give a few examples.

[3] Preparation of adamantane is a straightforward laboratory experiment. See *Organic Syntheses*, Collected Volume 5, ed. H E Baumgarten, John Wiley. pp. 16 – 19, 1973.

Regular *Resonance* readers would be familiar with the simple way of protecting a reactive species by providing bulky substituents at suitable locations. The adamantyl group is an ideal unit for this



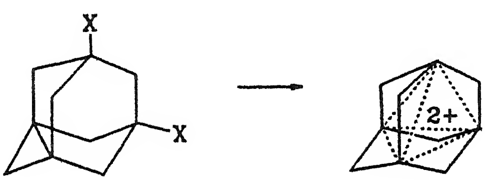
(2)

Adamantane belongs to a class of materials called *plastic crystals.*

purpose. A famous example in which the idea was tried out is the carbene, (2). While electronic stabilization is provided by the π electrons in the ring, the adamantyl groups shield the reactive site. As a result, the carbene is stable enough to be stored in a bottle. Later, it turned out that the electronic effect is more important, since the corresponding carbene with methyl substituents is also stable.

A beautiful example of a species with a 4-centre-2-electron bond was devised around the adamantane skeleton. The dication derived from dehydroadamantane (*Figure 3*) has been shown by Schleyer to adopt the tetrahedral structure, (3). The orbital lobes at the bridgehead positions have 'through-space' overlap. Two electrons are accommodated in the totally symmetric combination. In effect, (3) is a 3-dimensionally aromatic species.

Over the years, adamantyl derivatives have been used in mechanistic studies. The study of nucleophilic substitution reactions at saturated centres was often complicated by the occurrence of two processes, S_N1 and S_N2. Although the former is favoured in tertiary systems, contributions from the S_N2 mechanism could not be ruled out. The problem was resolved using 1-adamantyl



(3)

***Figure 3** Formation of a 3-dimensionally aromatic species from a dehydroadamantane derivative (X is a good leaving group).*

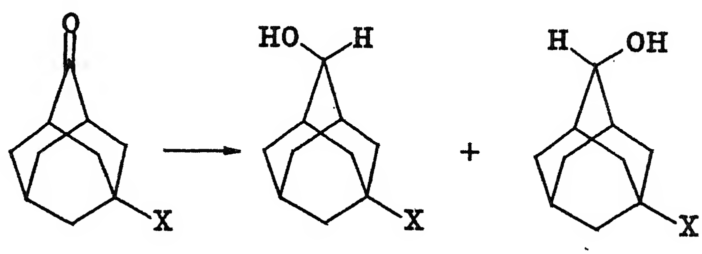
In recent years, the adamantyl skeleton has served as an important probe for studying long-range substituent effects.

derivatives. Since backside attack is not geometrically possible at the bridgehead position, the solvolysis reaction follows the S_N1 mode exclusively. The bridgehead cation is also fairly stable, allowing the reaction to occur easily. The 2-adamantyl cation is also an important reference system for secondary carbocations.

In recent years, the adamantyl skeleton has served as an important probe for studying long-range substituent effects. It has been shown that the preferred direction of approach of a nucleophile towards the carbonyl group of adamantanone can be controlled by substituents at the 5-position (*Figure 4*). Many interpretations have been and are being offered and debated. The problem of π-face selectivity in organic reactions induced by remote substitution is currently an active area of research in physical organic chemistry.

There have been other uses for adamantane. The solid has served as a host for studying small free radicals. On recrystallisation of adamantane, some solvent molecules usually get trapped in the defect sites. Using X-rays or γ-radiation, radicals derived from the solvent can be generated. The *electron spin resonance* spectrum of the radical is often simple to interpret. This is because the radical tumbles freely in the adamantane matrix, giving rise to simple 'solution' (isotropic) spectrum of the radical.

The adamantyl group is large, inert, and hydrophobic. It can be incorporated suitably to make fat-soluble drugs. Therefore, some



X = F	59	:	41
X = $SnMe_3$	45	:	55

Figure 4 Examples of π-face selectivity in nucleophilic additions to 5-adamantanone derivatives. Note that the adamantane skeleton is drawn in a different orientation to highlight the similarity of the two π-faces of the carbonyl unit.

medicinal applications have been considered. For example, adamantyl amine shows anti-viral activity. But some applications are quite unusual. High molecular weight fluorocarbons with high symmetry have been proposed as artificial blood substitutes. These chemically inert molecules dissolve oxygen, but little else, and hence may be suited for oxygen transport. Perfluoroadamantane is an important candidate considered in this context.

The adamantyl group is large, inert, and hydrophobic and can be incorporated suitably to make fat-soluble drugs.

It is easy to see why chemists are enamoured by adamantane and related cage compounds. Adamantane chemistry is rich. It offers many pleasant surprises. It provides answers to many questions in physical organic chemistry and raises some new questions.

Suggested Reading

- Organic Syntheses. Collected Volume 5, ed. H E Baumgarten. John Wiley, pp.16-19, 1973.
- S Ranganathan. *Resonance*. Vol.1, No.1, pp.28-33, 1996.

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Karl Popper on Darwinism...

At first sight Darwinism (as opposed to Lamarckism) does not seem to attribute any evolutionary effect to the adaptive behavioural innovations (preferences, wishes, choices) of the individual organism. This impression, however is superficial.... the organism, by its actions and preferences, partly *selects the selection pressures* which will act upon it and its descendants.

From *Unended Quest* by Karl Popper.

Classroom

In this section of Resonance, *we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. "Classroom" is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.*

! The Concept of Experiment in Science

Samir Roy, Department of Computer Science and Engineering, NERIST, Nirjuli

Galileo established science as an independent and autonomous cognitive process. He achieved this with the introduction of the concept of *experiment* into the methodology of science. Prior to Galileo, science was just a part of philosophy in general where the method of obtaining knowledge was observation followed by intellectual speculation or, sometimes, purely intellectual speculation. Galileo distinguished science from philosophy, once and for all, by establishing experimentation as an indispensable tool of scientific cognition. Of course the scientific query, that is, asking questions about the nature of the physical world, and the subsequent human endeavour to discover the causal relationships among natural phenomena, is as old as the history of human consciousness. But the approach towards such questions was not essentially different from the approach of philosophy.

Though verification is the way to establish a scientific theory, the essence of a theory which is scientific lies in its fallibility rather than its verifiability.

Hence the cognitive process of science, as established by Galileo, consists of speculation (in the form of a hypothesis) – experimentation-verification. However, though verification is the way to establish a scientific theory, the essence of a theory which is scientific lies in its fallibility rather than its verifiability, as pointed out by Sir Karl Popper, the famous philosopher of

science of our age. Experimentation thus forms the very basis of scientific cognition. Therefore let us consider the concept of an experiment.

What really is an experiment? We shall try to grasp the concept of scientific experimentation with reference to a well known but simple experiment by Newton. The purpose of the experiment was to verify whether all bodies fall from a particular height with the same velocity. The notion that was prevalent at the time of Galileo was that heavier bodes fall more quickly than lighter bodies. Newton inserted a penny and a feather inside a long glass cylinder. He pumped out the air from the cylinder to minimize the resistance of the air during the fall. He kept the glass cylinder upright so that both the penny and the feather were at the bottom and then abruptly turned it upside down. He observed that the feather which is far lighter than the penny and the penny, both reached the bottom of the glass cylinder simultaneously, thus proving that the preconceived notion does not agree with reality, at least it does not agree with the outcome of the experiment.

To check the truth of a certain preconceived idea about a natural phenomenon Newton repeated the occurrence of that phenomenon deliberately in a contrived and artificial way; a way in which it never really occurs in nature. He demonstrated that the result contradicts the preconceived idea held till then.

Experimentation is a way to concentrate on the particular phenomenon we are concerned with.

In the world around us we never see things falling through vacuum. Still, to investigate the way things fall he tried to make them fall through vacuum. Why? Because he felt that the existence of air inside the cylinder is a disturbance, as far as the movement of a body towards earth is concerned. Why should we consider the existence of air to be a disturbance? Because we implicitly assume that the phenomenon of falling has nothing to do with air, they are totally unrelated. In this way science tacitly divides reality into myriads of compartments, presumably unrelated, and then strives to study them separately. Experimentation is a

A new theory is considered to be valid and in some sense closer to truth if its predictions agree with the results explained by the previous theory plus the new results which the old theory could not explain.

way to concentrate on the particular phenomenon we are concerned with. Ironically, the object of science is to find a pattern i.e. a causal relationship between diverse and apparently unrelated phenomena. This purpose is achieved as the scientist tries to find more generalized theories that embrace wider spheres of apparently unrelated phenomena (unrelated to our immediate sensory experience). For example, the phenomenon of high tide and low tide of the oceans and the fall of a mango from a tree are united through the theory of gravitation though, as far as our immediate sensory experience of these two phenomena is concerned, they are unrelated. Of course the scientist takes into account the knowledge already accumulated by the human race through ages.

Thus the essence of experimentation is to prepare an artificial environment, commonly known as the experimental set up, where for the sake of concentrating on a single phenomenon the occurrence of that phenomenon can be repeated in a manner detached from other phenomena. The main concern is to facilitate a particular aspect of reality to be highlighted. Based on the outcome of the experiment the scientist draws conclusions related to the phenomenon which either validates some hypothesis or falsifies it. So long as the theory is consistent with the results of the experiments it is considered to be valid. Whenever people begin to find phenomena which do not fit into the pattern already laid down by some previous theory, the theory is considered to be inadequate and scientists search for a new theory. A new theory is considered to be valid and in some sense closer to truth if its predictions agree with the results explained by the previous theory plus the new results which the old theory could not explain. The fate of the new theory is, perhaps, no better. This will also be made obsolete by some other theory which might be able to unite a larger number of phenomena through its explanations. In this sense any scientific theory is fallible, by virtue of its being scientific. Science believes that it gets closer to the truth in this way, and experimentation is the only methodological light that can help us to choose the right path in this endless journey.

! On Provability Versus Consistency in Elementary Mathematics

Shailesh A Shirali
Rishi Valley School
A.P.

A reader asks, "*Why is 1 not listed as a prime? After all, does it not satisfy the stated criteria for primality?*" This note is written in response to this question.

The layperson usually thinks that mathematics deals with absolute truths, and indeed this was how mathematics was viewed during earlier centuries. However ever since the epochal discoveries of Bolyai, Lobachevsky and Riemann that there can be geometries (note the plural) other than the one presented in Euclid's text *The Elements*, this implicit notion had to be dropped. Even the notion that everything in mathematics is provably true or provably false had to be abandoned, after the astonishing results obtained by Gödel in 1930. Alongside this development, mathematics has seen a pioneering and extremely productive method: the axiomatic method, in which new areas of mathematics get created merely by defining suitable sets of axioms. As a result, the accent in mathematics has to some extent shifted to the study of axiomatic systems, and the essential question in such cases has become one of consistency and richness of the axiom system rather than its intrinsic truth or falsity. Much of modern algebra, starting with group theory, the theory of fields and rings and vector spaces and so on can be viewed in this light. Loosely speaking, one might say that in the modern mathematical paradigm, *true* is roughly equivalent to *consistent* while *false* is equivalent to *self-contradictory*[1].

[1] It is an interesting commentary on the psychology of modern mathematicians that, when pressed, most of them will readily say that there is no such thing as absolute truth in mathematics, and that a mathematical proposition is true or false only with reference to a particular axiomatic system. But amongst themselves most mathematicians 'know' that what they deal with does indeed refer to something 'concrete', 'real' and 'absolute'!

Here are some instances to illustrate the theme of consistency as opposed to absolute truth. In school arithmetic, one encounters the question, "Why is $-1 \times -1 = 1$?" Many 'proofs' are offered, but the plain fact is that the relation is a *convention*, not an absolute truth, and therefore there is no question of proving it[2].One adopts it because of its implication for the law of distributivity of

[2] Here is a particularly preposterous proof which I encountered a few years back: the parabola $y=x^2$ is symmetric in the y-axis, therefore minus times minus equals plus!

multiplication over addition (LDMA for short), according to which $a(b+c) = ab+ac$ for all a, b, c. The LDMA is too valuable an axiom to lose! Here is roughly how it happens. Starting with **N** the set of positive integers, with $\times$ and $+$ defined on **N** in the usual manner, we enlarge the set by including 0 and imposing the following rules:

$$a+0 = 0+a = a, \ a \times 0 = 0 \times a = 0.$$

Note that the two statements are consistent with one another because of the LDMA. For example, $2 \times 3 = 2 \times (3+0) = 2 \times 3 + 2 \times 0$, so we must have $2 \times 0 = 0$. Next, one constructs the negative numbers via the rule $a + (-a) = 0$. To do addition we call upon commutativity and associativity. For instance we have:

$$(-2) + (-3) + (2+3) = (-2) + 2 + (-3) + 3 = 0 + 0 = 0.$$

Therefore $(-2) + (-3) + 5 = 0$ and $(-2) + (-3) = -5$.

Finally, multiplication is taken up, and here one invokes distributivity. We find that we are forced to adopt the convention that $-1 \times 1 = -1$ and $-1 \times -1 = 1$:

$$0 = 0 \times 1 = \{(1+(-1)\} \times 1 = \{1 \times 1\} + \{(-1) \times 1\} = 1 + \{(-1) \times 1\},$$

therefore $(-1) \times 1 = -1$; and,

$$0 = \{1+(-1)\} \times (-1) = \{1 \times (-1)\} + \{(-1) \times (-1)\} = -1 + \{(-1) \times (-1)\},$$

therefore $(-1) \times (-1) = +1$. *The point is that we need these relations if we are to preserve the LDMA, which we cannot afford to lose. The consistency of the system must be preserved at all cost*[3].

[3] Sacrificing the LDMA would mean that we lose the ring structure of Z.

Here is another question, also asked at the school level: Why is $a^0 = 1$ for all $a > 0$? We proceed to resolve this in a similar vein. Let $x, y \in$ **N**; then $a^{x+y} = a^x \times a^y$ and $a^{x-y} = a^x / a^y$ when $x > y$. These follow from the very meaning of a^n when n is a positive

integer. What do we do with a^0? If we wish to have a system of algebra that is consistent and easy to work with, then we need to adopt the convention that $a^0=1$. There is nothing absolute about this. Rather, we *choose* to give a^0 a meaning that makes it easy to deal with. In short, we make a^0 a well-behaved object. (Note that 0^0 cannot be given any consistent meaning, nor 0/0; that is, it is not possible to make these objects well-behaved.)

Finally we take up the question: "*Is 1 a prime?*" We recall the fundamental theorem of arithmetic (FTA): *Every integer $N > 1$ can be expressed in just one way as a product of primes, except possibly for the order of occurrence of the primes.* If 1 were included in the set of primes **P**, then the fact that $1^n = 1$ for all integers n would require us to rephrase the FTA by adding the clause "... except that 1 may occur to any arbitrary power." We would end up labelling 1 as a special prime, to be excluded from most of the interesting theorems about prime numbers. Indeed, what would in all likelihood happen is that theorems about primes would end up being phrased in terms of the set $\mathbf{P}' = \mathbf{P}\backslash\{1\}$. Thus giving 1 membership in **P** proves to be a nuisance, and it is simpler to keep it out right at the start.

The accent in mathematics has to some extent shifted to the study of axiomatic systems, and the essential question in such cases has become one of consistency and richness of the axiom system rather than its intrinsic truth or falsity.

The matter can be considered from another viewpoint. Let **Z** denote the set of integers, and consider the set of complex numbers of the form $a + bi$, where $a, b \in \mathbf{Z}$, and $i = \sqrt{-1}$. These are the *Gaussian integers* first studied in detail by Gauss, and the set of such numbers is denoted by $\mathbf{Z}(i)$. (Note that **Z** is a subset of $\mathbf{Z}(i)$.) Now in **Z**, the only elements that possess multiplicative inverses are ± 1 (that is, their reciprocals lie within the same set); these are the *units* of **Z**. In $\mathbf{Z}(i)$, the set of units turns out to be $\{\pm 1, \pm i\}$. (The reader is invited to verify that there are no other units in $\mathbf{Z}(i)$.) Arithmetic can be done in $\mathbf{Z}(i)$ just as it is in **Z**; for instance, we can factorize numbers:

$$9 + 7i = (2+3i)(3-i),\ 13 = (2+3i)(2-3i), \ldots.$$

Observe that 13, which is prime in **Z**, loses its primality status in $\mathbf{Z}(i)$.

We declare a number $z \in \mathbf{Z}(i)$ to be *prime* if z is not a unit and if in every factorization $z = uv$, with $u, v \in \mathbf{Z}(i)$, either u or v is a unit[4]. The reader is invited to verify that 3, 7 and $2+3i$ are Gaussian primes, whereas 2, 5 and 13 are composite (because $2 = (1+i)(1-i)$, $5 = (1+2i)(1-2i)$, etc.). We now have the result: *every number in $\mathbf{Z}(i)$, not 0 or a unit, can be written as a product of Gaussian primes; moreover, there is essentially only one way of doing this*[5]. That is, we have an analogue of the FTA for the Gaussian integers, provided that the units are not considered as primes.

Other such number systems can be constructed. Indeed, once one grasps the idea, such systems seem to be available in abundance and can be spotted in many settings. For instance, consider the set $\mathbf{Z}(\sqrt{2})$ whose elements are number of the form $a+b\sqrt{2}$ where $a, b \in \mathbf{Z}$. This system presents itself quite naturally when one tries to solve the equation $x^2 - 2y^2 = \pm 1$ in integers. A striking fact about $\mathbf{Z}(\sqrt{2})$ is that it has infinitely many units. (The reader is invited to solve this. Hint: Show that $\sqrt{2} - 1$ and its integral powers are units; (harder) show that these are the *only* units of $\mathbf{Z}(\sqrt{2})$.) What are the primes of $\mathbf{Z}(\sqrt{2})$? It turns out that $\sqrt{2}$ is prime, as are the numbers 3, 5 and 11, but not 7, because $7=(3-\sqrt{2}) \times (3+\sqrt{2})$, nor 17, because $17=(5-2\sqrt{2}) \times (5+2\sqrt{2})$. It is an interesting exercise to classify the primes of $\mathbf{Z}(i)$ and $\mathbf{Z}(\sqrt{2})$. Is there an analogue of the FTA for $\mathbf{Z}(\sqrt{2})$? The answer is "yes", though it is hard work to prove it. However there are numerous number systems that closely resemble $\mathbf{Z}(i)$ and $\mathbf{Z}(\sqrt{2})$ but which do not have the FTA property. An example is $\mathbf{Z}(\sqrt{10})$: it can be shown that 2, 3, $4-\sqrt{10}$ and $4+\sqrt{10}$ are primes in $\mathbf{Z}(\sqrt{10})$, yet

$$6 = 2 \times 3 = (4-\sqrt{10}) \times (4+\sqrt{10}),$$

providing a counter example to the FTA. Perhaps it is phenomena of this type that make number theory a fascinating subject. As the reader will have noted by now, the word *prime* no longer carries a fixed meaning; it acquires meaning only with

[4] Since this article deals with terminology, it should be pointed out that what we refer to as 'prime' here is usually called 'irreducible' in the standard texts. In the standard definition, p is prime if we have the implication $p \mid ab \Rightarrow p \mid a$ or $p \mid b$. In the class of rings known as UFD's the two notions coincide. Examples of UFD's are Z, Z(i) and Z($\sqrt{2}$). However Z($\sqrt{10}$) is not a UFD.

[5] Units may enter the picture, hence the use of the words 'essentially only one way'.

reference to a particular context[6]. The interested reader could consult the well-known text by G H Hardy and E M Wright (*An Introduction to the Theory of Numbers*, Chapters XIV and XV) for further details.

[6]Historically, many of these developments were a result of efforts to prove Fermat's last theorem. See *Resonance*, Volume 1, No. 1 for more details.

Here is another example of axiomatic generalization. A rational number can be thought of as a root of the equation $mx+n = 0$, with $m, n \in \mathbf{Z}$, $m \neq 0$; here $m = 1$ gives us the integers — we call these the *rational integers*. Generalizing, we define an *algebraic number* as a root of the polynomial equation $ax^n + bx^{n-1} + cx^{n-2} + \cdots = 0$ with $a, b, c... \in Z$, $a \neq 0$ and $n \in \mathbf{N}$; if $a = 1$ then we have an *algebraic integer*. It is a non-trivial fact that the set **A** of *algebraic integers* is closed under addition and multiplication but not under division. Thus **A** behaves very much like **Z**, and we have at hand a genuine generalization of the notion of integer.

These examples may serve to highlight the extraordinary freedom that the axiomatic approach brings into mathematics. Some critics complain, however, that in exercising this freedom mathematicians tend to "go too far"; but that is another matter altogether and we shall not address it in this note.

TAILPIECE: Mr T B Nagarajan of Thanjavur has sent me the following problem: *Find four distinct positive integers such that the sum of any two of them is a square.* He writes that the problem is not too hard if the restriction on positivity is removed, or if one is content with solutions having very large integers. In support of this statement, he lists the following solutions:

$$\{55967, 78722, 27554, 10082\}, \{15710, 86690, 157346, 27554\}.$$

Readers are invited to take a crack at the problem. (To find a *triple* with the stated property is much easier; an example is provided by $\{6, 19, 30\}$. Readers may enjoy trying to list further such triples before going on to the more challenging four-number problem.)

Think It Over

This section of* Resonance *is meant to raise thought-provoking, interesting, or just plain brain-teasing questions every month, and discuss answers a few months later. Readers are welcome to send in suggestions for such questions, solutions to questions already posed, comments on the solutions discussed in the journal, etc. to* Resonance, *Indian Academy of Sciences, Bangalore 560 080, with "Think It Over" written on the cover or card to help us sort the correspondence. Due to limitations of space, it may not be possible to use all the material received. However, the coordinators of this section (currently A Sitaram and R Nityananda) will try and select items which best illustrate various ideas and concepts, for inclusion in this section.

Rajaram Nityananda, Raman Research Institute, Bangalore.

1 Capillarity

1) What happens if the height of the tube is less than the value given by the formula above? Would the liquid squirt out? (Beware of perpetual motion!)

2) The formula contains the quantity T, which is a property of the liquid, but does not appear to contain any property of the material of which the capillary tube is made. This is surprising, because surely it is the attractive force between the material of the tube and the liquid which is responsible for the liquid rising against gravity! What is going on?

*Discussion of question raised in **Resonance**, Vol.1, No.5.*

In spite of the warning against perpetual motion, some readers felt that the liquid would pour out of the top of the tube!

P Viswanath of Vellore pointed out that what matters is the radius of curvature of the 'meniscus' i.e the liquid surface. In its attempt to rise beyond the top, the liquid surface can take a spherical shape with a larger value r' (marked **c** in the figure) than the radius r of

RESONANCE

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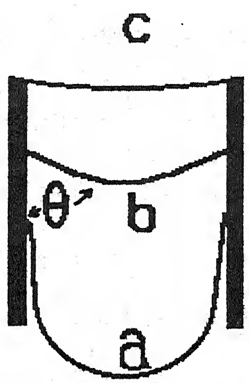


a. Meniscus when the liquid wets the walls. Note the zero contact angle and the thin film rising above.
b. Shape of the meniscus for contact angle θ.
c. Even with zero contact angle, the meniscus adjusts its radius of curvature at the top of the tube.

the tube. $2T/r'$ can then balance $h\rho g$ for the height h which is less than $2T/r$. Viswanath very properly points out that D S Mathur in his textbook on *Properties of Matter* gives this explanation. P Viswanath, Sulva Bhattacharyya (Jadavpur) and P K Thiruvikraman (Bangalore) all brought up the contact angle θ. This is the angle between the tangent to the liquid surface and the tube wall (see the surface marked **b** in the figure). Our formula assumed that this was zero, and the more general formula is $h = 2T\cos\theta / r\rho g$. This is one way in which the material of the wall can influence the capillary rise.

But there is one more twist to the story. We say the liquid wets the surface when the contact angle is zero — for example water wets a range of different materials. In all these cases, h has the same value! D Tabor, in his beautiful book *Gases, Liquids and Solids*, remarks that in this case, a thin film of the liquid covers the surface of the capillary above the meniscus (see the surface marked **a** in the figure). The attraction is now between water and water, and hence does not depend on the material of the wall, *once the wetting condition is met.*

Mohan Delampady, Indian Statistical Institute, Bangalore

2 St. Petersburg Paradox

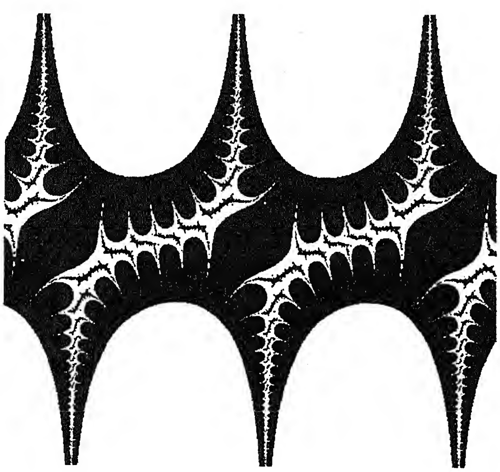
Consider the following gambling game. First you pay a fee, say Rs 10, to play this game. Then you go on flipping a *fair* coin until a tail first appears. Your reward will be Rs 2^n if you make the coin come up heads $n-1$ times before a tail appears. For example, if the outcome is *HHHT*, you win $2^4 = 16$ rupees. Your expected gain from playing this game is

$$\sum_{n=1}^{\infty} (2^n - 10)\, P(n - 1 \text{ heads followed by a tail}) =$$

$$\sum_{n=1}^{\infty} (2^n - 10)\, 2^{-n} = \infty$$

In fact, the expected gain is ∞ not just for the fee of Rs.10 (that you need to pay first) but for any fixed amount, however large. But most of us will not play this game for a large fee. Why?

Fractals



Galaxies — Off to a Flying Start?

New Telescopes Tell us Stars Were Made Very Early

R Nityananda

One of the basic questions in astronomy is simply — when did galaxies form? To answer this by observation, astronomers take advantage of the finite speed of light. When we look at the most distant objects in the universe, we also see them as they were when the light started its journey billions of years ago. A study of the geography of faraway galaxies thus becomes a study of their history as well! Two consequences of this long journey have to be kept in mind. These distant objects appear very faint, since the radiation has been spread out over a sphere of radius equal to the distance. And, because of the expansion of the universe, the wavelength of the light received is longer than that emitted. This is the famous redshift, which was the basic observation which led to the idea of an expanding universe. Each quantum of light has a lower frequency and hence a lower energy, further weakening the signal received. But this can actually be turned to advantage. From the ground, we usually do not see the ultraviolet region of the spectrum, since it is absorbed by the earth's atmosphere. A photon which starts out in the far ultraviolet, say at 800 angstroms, would encounter clouds of hydrogen on the way which could absorb it and use the energy to liberate the ground state electron. However, a photon with wavelength longer than 912 angstroms does not have enough energy to do this. There is thus a break in the spectrum we receive at this wavelength (see *Figure 1*).

With this background, one can appreciate the principle of the search for very young galaxies conducted by Lanzetta and colleagues, reported in *Nature* (27 June, 1996). They used data from the Hubble space telescope, which now comfortably detects galaxies which are 10^{11} times fainter than the brightest stars we see in the sky! Such objects are too faint to obtain a spectrum in a conventional sense. But one can get a rough picture of the wavelength distribution of the incoming light by using four filters. In a small fraction of the objects, there was emission in a filter centred at 8000 angstroms but no emission was detectable at shorter wavelengths. This pattern was not seen for the brighter and hence presumably nearer objects in their study. The simplest explanation is as follows. Wavelengths shorter than about 6000 angstroms are being removed from the spectrum of these objects by intervening clouds of hydrogen. The wavelength of the light when it passed these clouds was therefore

They used data from the Hubble space telescope, which now comfortably detects galaxies which are 10^{11} times fainter than the brightest stars we see in the sky!

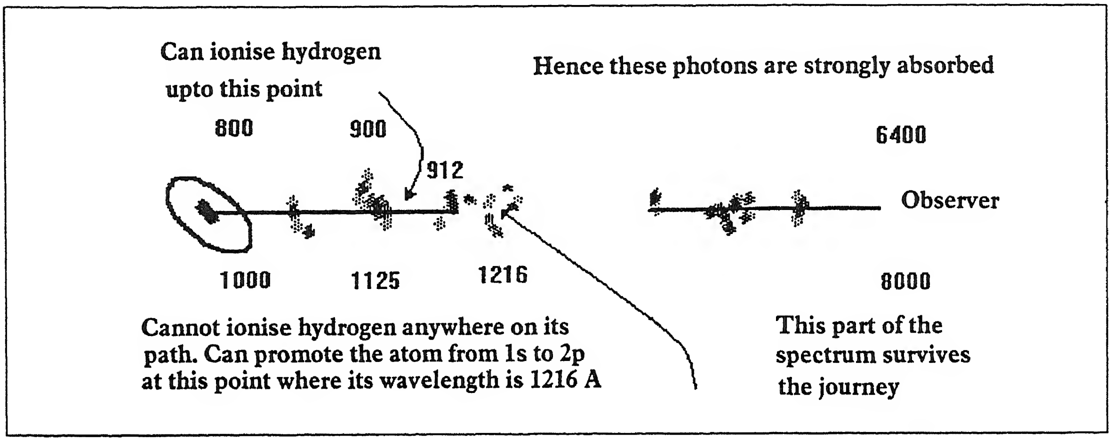


Figure 1 Journey of two ultraviolet photons from a distant source of redshift 7 to the observer. Those with wavelengths shorter than 912 angstroms are absorbed by clouds of hydrogen atoms on the way.

shorter than 912 angstroms. This means that in its journey, the wavelength has got stretched by a factor of seven or eight. Astronomers like to subtract one from this number before calling it a redshift. (This makes sense since no shift corresponds to a wavelength ratio of 1.) Thus, the absorption occurred in clouds at redshift greater than six. These objects were formed at or before a time when the size of the universe was seven times smaller than now! The number of such objects found is also interesting. After scaling up from the small area studied, it roughly corresponds to the number of galaxies seen today. Add to this the fact that the first burst of star formation is expected to give ultraviolet light which would now appear in the 8000 angstrom band, and the overall interpretation becomes attractive.

A few years ago, the simple model in which the density of the universe was very close to the critical value, was quite popular. This value separates the case when the universe recollapses, from the case when it expands forever. In this model, the age at redshift six was fifty times less than the figure of about 12 billion years today. A mere quarter billion years from the big bang and already forming stars? Theoretical cosmologists would regard this as surprising, and would probably look to other models.

The other piece of work bearing on the formation of galaxies is a rather different kind of observation. Dunlop and coworkers report

A few years ago, the simple model in which the density of the universe was very close to the critical value was quite popular.

in *Nature* (13 June, 1996) their study of a galaxy, bearing the name 53W091, which is about twenty times brighter than the faint members of the previous study. This galaxy would still have been regarded as barely detectable three years ago. Using the biggest ground-based instrument, the W M Keck 10 metre diameter telescope in Hawaii, they were able to obtain a spectrum in just a few hours of observations. And this was a genuine spectrum, not one with four points as in the previous study. It could therefore be compared in detail with the spectra of nearby galaxies and the stars in them. The wavelengths were stretched by about two and a half, which of course makes it a much closer object, at redshift 1.5. It is therefore being seen at a much later phase of the expansion of the universe, compared to redshift 6 of the previous study. Many such objects are already known. But the surprise was that the spectrum strongly suggested a *middle aged* galaxy, at least three and a half billion years old. One finds absorption lines of elements like calcium, very much like those in the sun, which is five billion years old. Most other galaxies spotted at a redshift of one and a half tend to show signs of youth and activity. So this one exception tells us that at least three and a half billion years were needed for the universe to expand from a very small size (the big bang if you like) to a stage when it was two and a half times smaller than it is today. Again, this can be compared with the model of a critical density universe, In which the age increases as the square of the expansion factor, the age now is 3.5 billion years, multiplied by 6.25 (i.e. 2.5^2). The result 22 billion years is far too long for comfort! (we quoted 12 billion years earlier). The authors rightly conclude that the critical density model is "in difficulty". Even lowering the density in the model of the universe gives an interesting result. This galaxy formed at redshift greater than four. Combine this with redshift six from the previous study. The overall picture emerging is that the universe is forming galaxies early, even if theoretical cosmologists are not quite sure how. And remember that these magnificent telescopes like Hubble and Keck have only just started looking at the sky. More exciting news from the depths of space and time can be expected.

The overall picture emerging is that the universe is forming galaxies early, even if theoretical cosmologists are not quite sure how.

Suggested Reading

- Origin (?) of the Universe – V by J V Narlikar, *Resonance*, June 1996 in particular. Further references are available in the same series of articles.

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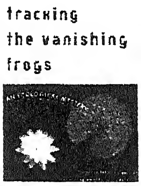
Take the Frogs Seriously – They are the Earth's Living Barometers

A Book for One and All

Debjani Roy



Tracking the Vanishing Frogs
Kathryn Phillips
Penguin Books, 1994
pp.ix+244, $11.95

As an amphibian biologist, reading the book *Tracking the Vanishing Frogs* churned up mixed feelings in me. On the one hand, I was relieved to learn that people have started thinking seriously about the issue of declining amphibian populations. On the other hand, I was disheartened to note that even today, amphibian biologists are a minority community worldwide.

This is a superb book that will appeal to the young and old alike. Written in the context of the present global environmental crisis, it explains how frogs and toads serve as living thermometers. Their declining populations draw attention to the pressing need to draw up action plans for their protection. Kathryn Phillips uses the example of the red-legged frogs to make her point. Under normal circumstances these frogs lay about 680 eggs that have a 91% chance of hatching. But the tadpoles have only about a 5% chance of actually making it to metamorphosis and only about half of these frogs survive a full year. All these numbers taken together mean that only about 2.5% or 17 of the 680 eggs laid, actually survive to the one year old frog stage. Considering that it takes 3 years of dodging predators and bad luck before they reach adulthood, the odds are even smaller that one of these eggs will eventually become a breeding frog. If this is the case under normal circumstances imagine the deleterious effects of the changing environment on the size of frog populations.

Phillips, herself a journalist, has written the book in true journalistic spirit. She has taken pains to collect relevant information, travelled widely, accompanied biologists on their field trips, watched them catch frogs in marshes and ponds at night, interviewed scientists and attended conferences. Armed with this experience, the author has written in minute detail about the alarming situation of disappearing frogs. Environmental changes such as decreased ground-level and underground moisture and temperature changes, make the soil acidic leaving amphibians susceptable to bacterial, parasitic and viral infections and other air and water pollutants.

She writes the story of scientists and captures the anxieties and problems in their search for answers. She also deals with subjects, which

> Written in the context of the present global environmental crisis, it explains how frogs and toads serve as living thermometers.

›wever trivial like the status consciousness biologists, working conditions in the field, e formation and running of scientific acad-nies, and the price of publicity, have a defi-te role in the growth of science and the ademic world. She gives a graphic descrip-ɔn of scientific conferences: "In science, ›nferences are a weird combination of final :am, political convention and networking ırty. The heart of any conference is the :searchers' presentation of the paper about ıeir work. The conference becomes their rst public unveiling, a chance to weigh their ɐer response and answer unanticipated criti-.sm. But the real action, just as in any politi-ıl convention, often occurs away from the odium. In the conference center hallways, ›bbies, bars and restaurants, ideas are floated, ›bbying is conducted, gossip is shared and ›bs are offered." Again she has not failed to otice that at times "Sharing information is a ɔuchy subject with many scientists, in and ut of herpetology. They live in constant fear hat they will be "scooped" or won't get proper redit for their work. Credit for work can nean the difference between employment nd unemployment, between promotion and tagnation, between getting funding and not ;etting funding. In herpetology, the pressure ıas helped create a field divided into a variety ›f competing camps. There are academic esearchers who won't share data with ›iologists working for the various federal and ;tate agencies. There are state and federal ıgency biologists who won't again share with ɐach other."

The book makes pleasant reading as it describes the people whose work is referred to in the articles.

The book makes pleasant reading as it describes the people whose work is referred to in the articles. Reading about their experiences is very interesting — such as when we read about Mark Jennings: "If Jennings had not become a scientist, he would have become a historian. An inveterate collector of biographical information about early biologists, particularly those who made their mark studying amphibians or fish, he can recite long anecdotes about the ways in which some of the famous biologists carried out their work, what kind of field notes they kept, who trained them and who they trained in turn. He uses the early researchers as mentors and often adapts their habits."

I am sure that had a biologist written this book she or he could not have given us the graphic descriptions that Phillips has put together as a result of her experience. Phillips has combined serious science dealing with amphibian evolution, systematics, behaviour, altruism, kin recognition, various methods of reproduction, taxonomy and the effects of uv-β radiation with art, literature and folk culture. In her writing, frogs appear as demons, connivers, saviours, good-luck charms and simple goofy characters with kind, outsized hearts. In more than one culture these animals are believed to induce fertility in humans.

She also writes about the effects of sociocultural events such as the 'California gold rush' on frog populations. She does not stop there, but goes on to give us the recipe for a preparation of frog legs: "the legs are often prepared with chicken soaked in milk, dusted with flour, then fried." In the concluding pages the author makes a beautiful comparison between canaries and frogs. The caged canaries were used as indicators for dangerous leaks in the mines and similarly frogs can be used as bioindicators for the earth's environmental changes.

Readers will enjoy every page. It will not take the reader much time to read the book – all the varied information is put together in a lucid paperback of only 244 pages with lovely colour photographs and detailed references.

Debjani Roy is with the Institute of Self Organising Systems and Biophysics, North Eastern Hill University, Shillong 793 008.

In *Scientific American*, 1877

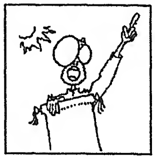
The editors of Scientific American who have just witnessed a remarkable demonstration of new technology in their offices, recall the event for readers: "Mr Thomas A Edison recently came into this office, placed a little machine on our desk, turned a crank, and the machine enquired as to our health, asked how we liked the phonograph, informed us that it was very well, and bid us a cordial good night."

In *Scientific American*, 1947

Edwin H Land is reported to have invented a camera that develops its own film, in about 60 seconds, without the need for a darkroom. The Polaroid instant camera is marketed a year later (the color version appears in 1963).

(From *Scientific American*, September 1995)

Information and Announcements



Careers in Nature Conservation : The Wildlife Institute of India

Conservation of natural ecosystems, resources, and the diversity of living creatures is a major concern of humans today. As natural habitats shrink and disappear, species are being driven to extinction in many parts of the world. Most countries have therefore established sanctuaries, nature parks, and protected areas, as well as laws and institutions to tackle environmental problems. Within India, a premier institution dealing with nature conservation is the Wildlife Institute of India in Dehradun, Uttar Pradesh.

The Wildlife Institute of India (W.I.I.) was established in 1982 by the Ministry of Environment and Forests (MoEF) of the Govt. of India. By 1986, it was granted autonomy to pursue research, training and educational activities, while continuing to function under a governing body chaired by the Secretary of the MoEF. Today, W.I.I. is widely recognised as a major research and training institution in the field of nature conservation, management, and research in India.

The Institute has two major objectives. The first is research — mainly applied ecological research on endangered species, critical ecosystems and biogeographic areas. There is a strong emphasis on field-based research that addresses real-world conservation and management issues. The second focus is on education and training. Besides courses for in-service forest officers and wildlife managers, W.I.I. offers M.Sc. and Ph.D. degrees in wildlife science. In addition, the institute also provides expertise and consultancy services relating to wildlife and protected area management, environmental impact assessment, and environmental education and interpretation.

M.Sc. Wildlife Science: One of the major attractions of W.I.I. is the 2-year Masters programme in Wildlife Science. Students in this programme take three semesters of intensive course work in various relevant fields of ecology, behaviour, conservation, and management. Simultaneously, they

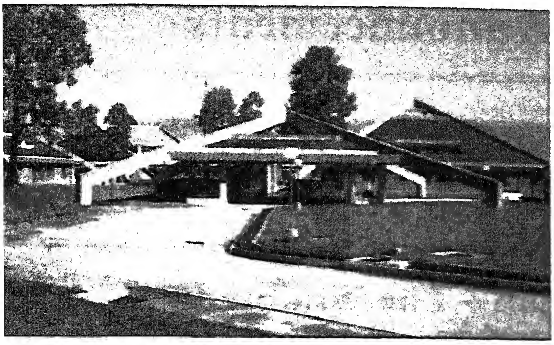


Figure 1 Snow-capped Himalayan peaks form a scenic backdrop to the W. I. I. campus buildings in winter. (Photograph by S Wilson).

undergo field training in various protected areas in different parts of India — an aspect of the course that the students invariably enjoy the most. The final semester is set aside for a field research project by the student (see *Box 1*). The courses offered at W.I.I. include various compulsory and optional subjects such as population and community ecology of plants and animals, biology of Indian wildlife ranging from invertebrates to mammals, animal behaviour. conservation biology, wildlife and forest management, habitat ecology, advanced field techniques, and quantitative methods in biology.

Admission to the M.Sc. course is offered every alternate year through a national entrance test. Usually, about 7-10 students are admitted, and at least six are provided a fellowship of Rs. 1,200/- p.m. during their course, in addition to extra funds for the final six-month field research project. Admissions will open again in 1997. Students are usually given a three-month additional fellowship of Rs. 2,000/- p.m. after completion of their M.Sc. course, and are encouraged by the faculty to prepare manuscripts for publication in journals and popular periodicals. Thus, in addition to their M.Sc. thesis, several students have research publications resulting from their work in national and international journals. Students who have graduated from the course have later joined various environmental NGO's, academic institutions, or gone ahead with further studies for a doctoral degree in the field.

Ph.D.: Every year, research projects are initiated by the various faculty of W.I.I. and candidates are awarded Junior Research Fellowships after an entrance test (usually in December) and interview. The candidate can register with the Saurashtra University (to which W.I.I. is affiliated) or other universities for their Doctoral degree. There is no course work involved and the students can directly begin their field research. Those interested in specific projects or more details can contact

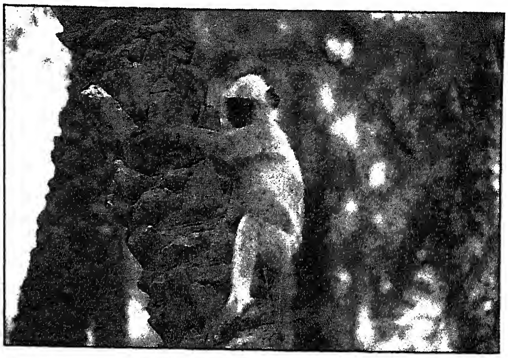


Figure 2 (top-left) Corals in the waters of the Marine National Park in the Gulf of Kutch, Gujarat - threatened by pollution and industrialisation. (Photograph by B C Choudhury).
*Figure 3 (top-right) A young Hanuman langur (*Prebytis entellus*) rests languidly on a tree trunk after its morning bout of feeding. (Photograph by T R Shankar Raman).*

the Wildlife Institute at the address given below

Ravi Chellam, Research Coordinator, Wildlife Institute of India, P. B. No. 18, Dehradun 248 001, U. P., India.Phone: (0135) 640112-640115, Fax: (0135) 640117,
email: wii.isnet@axcess.net.in

Campus, Facilities, and Faculty

The W.I.I. campus is located amidst scenic surroundings on the outskirts of Dehradun town, in the Dehradun valley, between the Siwalik hill ranges and the Himalaya (*Figure 1*). The campus has an excellent and growing library with numerous international journals, books, e-mail, and modern electronic reference facilities. The computer centre has IBM and Macintosh computers, DOS and UNIX systems, LAN and advanced computer software. There is also a state-of-the-art Geographical Information Systems centre for analysis of spatial data, satellite imagery, and aerial photographs. The faculty of W.I.I. are in three divisions: wildlife biology, wildlife management, and wildlife extension. There are at present 22 faculty members and over 25 Research Fellows in W.I.I.

The institute has hostel and mess facilities and quarters for the teaching staff on campus. A canteen and nearby *chai* shop are the centres for much discussion on wildlife, natural history, conservation, and less academic, but equally absorbing topics for

Some Research Projects Undertaken by W.I.I.'s M.Sc. Students.

(1) Effects of disturbance, salinity, and oil pollution on coral islands in the Gulf of Kutch.

Coral islands remind many of blue seas and summer vacations (*Figure 2*). They are, however, among the most critically endangered ecosystems, threatened by pollution, exploitation, and tourism, among other things. In an interesting field study in the Marine National Park in the Gulf of Kutch, Rohan Arthur addressed this important conservation issue. Comparing Pirotan and Narrara islands, he found that the former had higher levels of species diversity of coral as well as higher levels of disturbances such as sediment load, algal cover, and bleaching. This harkens back to the idea that intermediate levels of disturbance might help maintain higher diversity levels in the tropics. Rohan also set up experiments in the field to test the effect of crude oil (a common pollutant) and bittern (high concentration salt solution, a by-product of the nearby salt pans) on coral boulders. Comparing with controls, he found that both pollutants resulted in coral bleaching and sediment deposition on the now-inactive polyps. While recovery of corals was swift, Rohan's results indicate that chronic pollution and high sedimentation in turbid reefs would be detrimental to the coral communities.

(2) Are common langurs fussy about what they eat?

For people who prefer *haute cuisine* and caviar, animals that eat leaves must seem the most unselective creatures, with really bad taste, perhaps. Nevertheless, there's more to this than meets the taste buds. The common or Hanuman langur, one of the most common monkeys of India, is a leaf eater (*Figure 3*). Kaberi Kar-Gupta observed the kinds of leaves the langurs ate during winter and spring in Rajaji National Park in U.P. She found that langurs fed on parts of 51 plant species, including leaves, seeds, fruits, and flower buds. Eight plant species, however, accounted for 80% of their diet. In winter, when mostly mature leaves were eaten by the langurs, she found that they apparently chose species which had higher protein and lower fibre levels. In spring, when young leaves were abundant, the langurs were not choosy about the protein levels, and appeared to be mainly avoiding a high-fibre diet. Her results showed that langurs are quite careful about what they eat and their diet varies with the leaf properties of the tree species in their habitat.

the students. There are tennis, badminton, volleyball, and basketball courts on campus, a cricket-cum-football ground nearby, plus indoor table-tennis for those interested in sports. Nearby *sal* forests, a small patch of scrub vegetation on campus, are the regular haunt of the campus ornithologists and naturalists. Besides this, Rajaji Tiger Reserve, a few kilometres away, with a field-station and ongoing research and monitoring projects, is often visited by the students and researchers.

T R Shankar Raman obtained a Masters degree in Wildlife Science from the Wildlife Institute of India, Dehradun. He is currently a research scholar at the Centre for Ecological Sciences in the Indian Institute of Science.

Books Received

Stoichiometry (SI units). III ed.
B I Bhatt and S M Vora
Tata McGraw Hill
1996, Rs.180.

Digital Libraries. Dynamic Storehouse of Digitised Information
N M Malwad, T B Rajasekar, I K Ravichandra and N V Satyanarayan
New Age International
1995, Rs.475.

Tensor Calculus, Theory and Problems
A N Srivastava
Universities Press
1994, Rs.50.

Optimization Methods in Operations Research and Systems Analysis. III ed.
K V Mittal and C Mohan
New Age International
1996, Rs.135.

Elements of Cosmology
J V Narlikar
University Press
1996, Rs.65.

Science Matters
Robert M Hazen and James Trefil
University Press
1991, Rs.135.

Guidelines for Authors

Resonance - *journal of science education* is primarily targeted to undergraduate students and teachers. The journal invites contributions in various branches of science and emphasizes a lucid style that will attract readers from diverse backgrounds. A helpful general rule is that at least the first one third of the article should be readily understood by a general audience.

Articles on topics in the undergraduate curriculum, especially those which students often consider difficult to understand, new classroom experiments, emerging techniques and ideas and innovative procedures for teaching specific concepts are particularly welcome. The submitted contributions should not have appeared elsewhere.

Manuscripts should be submitted in *duplicate* to any of the editors. Authors having access to a PC are encouraged to submit an ASCII version on a floppy diskette. If necessary the editors may edit the manuscript substantially in order to maintain uniformity of presentation and to enhance readability. Illustrations and other material if reproduced, must be properly credited; it is the author's responsibility to obtain permission of reproduction (copies of letters of permission should be sent). In case of difficulty, please contact the editors.

Title Authors are encouraged to provide a 4-7 word title and a 4-10 word sub-title. One of these should be a precise technical description of the contents of the article, while the other must attract the general readers' attention.

Author(s) The author's name and mailing address should be provided. A photograph and a brief (in less than 100 words) biographical sketch may be added. Inclusion of phone and fax numbers and e-mail address would help in expediting the processing of manuscripts.

Summary and Brief Provide a 2 to 4 sentence summary, and preferably a one sentence brief for the contents page.

Style and Contents Use simple English. Keep the sentences short. Break up the text into logical units, with readily understandable headings for each. Do not use multiple sub sections. Articles should generally be 1000-2000 words long.

Illustrations Use figures, charts and schemes liberally. A few colour illustrations may be useful. Try to use good quality computer generated images, with neatly labelled axes, clear labels, fonts and shades. Figure captions must be written with care and in some detail. Key features of the illustration may be pointed out in the caption.

Boxes Highlights, summaries, biographical and historical notes and margin notes presented at a level different from the main body of the text and which nevertheless enhance the interest of the main theme can be placed as boxed items. These would be printed in a different typeface. Such a boxed item should fit in a printed page and not exceed 250 words.

Suggested Reading Avoid technical references. If some citations are necessary, mention these as part of the text. A list of suggested readings may be included at the end.

Layout It is preferable to place all the boxes, illustrations and their captions after the main text of the article. The suggested location of the boxes and figures in the printed version may be marked in the text. In the printed version, the main text will occupy two-thirds of each page. The remaining large margin space will be used to highlight the contents of key paragraphs, for figure captions, or perhaps even for small figures. The space is to be used imaginatively to draw attention to the article. Although the editors will attempt to prepare these entries, authors are encouraged to make suitable suggestions and provide them as an annexure.

Book Reviews

The following types of books will be reviewed : (1) text books in subjects of interest to the journal; (2) general books in science brought to the attention of students/teachers; (3) well-known classics; (4) books on educational methods. Books reviewed should generally be affordable to students/teachers (price range Rs.50 to 300).

New books will get preference in review. A list of books received by the academy office will be circulated among the editors who will then decide which ones are to be listed and which to be reviewed.

Acknowledgements

Resonance gratefully acknowledges the help received from the following individuals:

D Bhattacharyya
T Krishnan
V R Padmawar
V Pati
Jayant Rao

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Edited and published by V K Gaur for the Indian Academy of Sciences, Bangalore 560 080. Printed at Thomson Press (I) Ltd., Faridabad 121 007.

"…. You are surprised at my working simultaneously in literature and in mathematics. One of the foremost mathematicians of our century says very justly that it is impossible to be a mathematician without also being a poet in spirit. It seems to me that the poet must see what others do not see, must see more deeply than other people. And a mathematician must do the same…."

— Sonya in a letter to a friend in 1890

ISSN 09

Sonya Vasilievna Krukovskaya

(1850-1891)